Senior Physics Seminar
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What It Means To Count: Issues of Verification in Strategic Arms Treaties

Verification plays an important role in Strategic Arms Limitation Talks. Issues of verification can at times shape negotiations and treaties and at other times be shaped by the form of the treaty. Possible treaty outcomes need to be viewed in light of this constraining relationship. Technological and political factors reveal information about which consideration is dominant in a given set of negotiations.

Counting measures vary from quantitative to qualitative. A simple review of various measures supports the view that counts which provide a clearer measure of capabilities of an arsenal are more difficult to verify. Any discussion of the arms race must be couched in the context of counting measures.

Examining the growth of strategic missiles over the past fifteen years in light of various counting measures aids in understanding the arms race. In particular, the arithmetic growth of more qualitive factors presents evidence that, at least in missile production, the arms race is niether stopped or spiraling out of hand. This steady growth supports the view of institutionalization of the military industrial complex.

What It Means To Count:
Issues of Verification in Strategic Arms Treaties

by

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Preface

In order to be fair to the reader I must state my biases. I have been raised in the Mennonite Church, one of the historic peace churches, and my attitudes reflect this upbringing. In an analysis as occurs in this paper, issues of ethics are not prominant but do play some role. I hope that the paper has remained fairly objective.

Any sane person would agree that we do not want nuclear war. A plethora of information has been produced regarding the issue of nuclear weapons, so why write more? As I approach college graduation majoring in physics and mathematics I feel a need to understand this terrible thing that we physicists have unleashed on this world. Untill recently there has been a dichotomy between the scientists who build weapons and the average citizen. Fortunately, the renewed enthusiasm over the past few years to deal with nuclear weapons has brought with it a great deal of information about technical aspects of warfighting. In the past, all of us were told that these technical details were far too difficult to grasp and not important to understand. Now however, we can learn. In fact it is necessary for technology and political science to integrate in order to deal with this most pressing issue.

This paper is an attempt to bring out one area of this integration in order to assist in looking critically at issues in negotiating arms limitation treaties. Of course, it is by no means comprehensive. Additionally, I pose questions here rather than trying to give answers. There are no simple answers to just about any global issue facing us today, so we must first attempt to look at the underlying structure of any problem. By trying to understand problems stripped to their bare essentials, we can develope tools to cope with the intracacies and details of the whole.

"Thank you, Burrows, for that descriptive insight into the nuclear arms race."

Introduction

The concept of verification forms an important part of the foundation of arms limitation talks. This seems reasonable enough, after all what good is a treaty without assurance that its provisions will be upheld? Thus we seek to identify compliance or noncompliance with any particular treaty. It seems that without verification or mutual trust a treaty which limits weapons has value only as a piece of political propaganda. Of course the issue of verification is not nearly as simple as this sounds.

This paper will look closely at the role verification plays in shaping treaties and how verification procedures are determined by policies. We need to be able to understand when verification is determined by policy and when verification is being used to push other agenda. Recent developements such as cruise missiles and space weapons threaten to throw kinks into the verification process since they are difficult to verify.

Recently, President Regan asked Congress to fund further developement of anti-sattelite weapons because "I do not believe it would be productive to engage in formal international negotiations." As an aid explained, there is "no way to establish a verifiably effective ban" on such weapons. (Eagle-Beacon, April 3, 1984). Thus we build them to keep up with the Russians. If this trend continues in the future we must ask what role verification can play in controlling the arms race. Political structures and technological issues must be understood to critically evaluate such statements.

Nuclear wepons can be counted in many ways. An examination of counting measures reveals their relationship to verification. The context of counting measures is essential for understanding any statements about nuclear weapons systems. A review of recent arms growth in light of various counting measures reveals a picture of the 'arms race' and provides evidence for the institutionalization of the military industrial complex.

Verification

What exactly is verification? In our context it refers to the measures for determining fulfilment of the obligations of a particular treaty. Presently the United States (US) and the Union of Soviet Socialist Republics (USSR) use national technical means to keep track of the other's strategic arsenal. National Technical Means (NTM) is a nice way of saying spying. It refers to satellite reconnaissance, remote radar, electronic eavesdropping and other unobtrusive means of gathering data.

It seems that visual inspection at the sights where violations of a treaty might occur would be simpler and more reliable. However, closer examination reveals that On Site Inspection (OSI) does not cure all verification problems. Anything but a quite limited and controlled OSI is politically unrealistic. In a closed society such as the Soviet Union, OSI can arouse great fears of espionage. While the Western nations have advocated OSI for many years, they still maintain a high level of secrecy, also limiting the potential of

OSI. It is hard to imagine either side freely providing inspection of state of the art research and developement.

Interestingly enough the most recent rejection of OSI originated in western 'open' societies. Negotiations on a comprehensive test ban treaty (CTBT) failed in 1980 because the United States and the United Kingdom objected to the on sight verification measures proposed by the Soviet Union. All had agreed to allow ten inspection stations in both the US and USSR; a significant step for the Soviets in light of their historic secretiveness. The Soviets asked for ten stations in the UK also, however the UK would accept only two such stations (Craig 1984 p.4-20). The difference caused the US and UK to abandon discussions.

Even if we overlook its political problems, on sight inspection by itself is not as effective as national technical means for gathering data about arms proliferation. Both the US and USSR are geographically quite large nations. Without satellite reconnaissance to detect major factories, missile fields, troop movements etc. visual observation could not begin to even locate all activities with any degree of confidence.

When linked with national technical means, on sight inspection could be useful to check on ambigious activities. The question of how to decide if an ambigious activity needs checking is unclear. Without checks, the ability to challenge all ambigious activities could be abused for propaganda or intelligence gathering. Thus the question of how to control a monitering group presents its own problems (Greb and Heckrotte p.219). Today satellites can distinguish objects as small as fifteen centimeters. Radiation in visable, ultraviolet and infrared ranges can be monitered so that darkness and cloud cover do not hamper detection (SIPRI 1980 p.188). Even though buildings can hide activities, monitering what goes in and out of the building can catch any large scale production activities.

Table 1 (p.7) lists methods of verification of a proposed nuclear freeze. This is similar to verification methods in Strategic Arms Limitation Talks (SALT) treaties (SIPRI 1980 p.304). Note that all but the last two columns, human intelligence (HUMINT) and on sight inspection, are NTMs. It is reasonable to assume that HUMINT shall be uneffected by any treaty given established intelligence gathering bodies. Thus the table shows OSI useful only for detecting ambigious activities. Any activity which is small enough to remain ambigious will be unlikely to provide a significant strategic threat (Aspin 1979). Thus OSI is useful mainly for detecting marginal cheating or underground bomb tests.

Having briefly defined modes of verifying strategic nuclear weapons, we will step back and look at the need for verification in arms treaties. In general verification is not a necessary condition for all arms controll agreements. If the signatories sufficiently trust each other there is no need for such provisions. The classic example of this is the 1817 Rush-Bagot agreement between the US and Britain

Table 1

VERIFICATION OF A NUCLEAR FREEZE: TASKS AND SYSTEMS

MONITORING TASKS: / INTELLIGENCE SYSTEMS:	Imaging Reconnaissance Satellites	Electronic Reconnaissance Satellites	Ocean Surveillance Satellites	Missile Warning Satellite	Nuclear Explosion Detection: Satellites "Vela Hotel" IONDS	Nuclear Explosion Detection: Ground-based Seismic Sensors	Acoustic Underwater Surveillance	Ground Based Monitoring Posts	Test Observation Radars	Aircraft and Ships	HUMINT and Overt Collection	On Site Inspection	Overall Monitoring Confidence Level (estimate)
I. Deployment Freeze													
A. Count fixed ICBM/IRBM launchers*	X	X											high
B. Count mobile ICBM/IRBM/GLCM launchers*	X	X											high moderate
C. Count SLBM launchers*	X	X	X										high
D. Count launchers for MIRVed missiles*	X										Counting Rule		high
E. Count strategic bombers (incl. ALCM)*	X	X											high
F. Count other primary nuclear mission aircraft (e.g., FB-111, Backfire...)	X	X						X		X	X		high moderate
G. Count nuclear-armed ships/subs (incl. those with SLCMs, ASROCs, SUBROCs,...)	X	?	X				X			X	X		high moderate
H. Count nuclear artillery/battlefield missile units, weapon depots	X	?						?		X	X		high moderate
II. Delivery Vehicle Testing Freeze													
A. To monitor (prohibited) testing of new ICBMs/SLBMs/IRBMs, monitor flight tests of existing missiles to detect:													
1. Changes in length, diameter, launch-weight and throw-weight (no greater than 5%)	X	X						X	X	X	X		moderate-high moderate
2. Number of stages/type of propellant (no change permitted)	X	X						X	X	X	X		high moderate
3. Number of RVs (no increase from maximum number tested for each type)	?	X						X	X	X	X		high
4. Weight of RVs (no decrease from lightest test flown)		X						X	X	X	X		high moderate
5. RV performance (no increase in ballistic coefficient above maximum already tested and no maneuvering)	?	?							X	X	X		high
B. Monitor limit on operational ballistic missile flight tests (6 or less per year)	X	X	X	X			X°	X	X	X	X		high
III. Nuclear Weapons Testing Freeze (CTB)													
A. Detect ambiguous seismic events						X	X						high moderate
B. Monitor activity/geography at potential test sites	X	?	?					?		?			high moderate
C. Detect evidence of nuclear explosions on land/in sea/air/space				X	X	X	X			X			high moderate
D. Identify ambiguous events												X	moderate-high moderate
IV. Ballistic Missile/Strategic Bomber/SSBN Production Freeze*													
A. Monitor shut-down of existing main assembly plants and shipyard(s)	X												high
B. Detect ambiguous activity at other facilities	X	X						X°	X°	X°	X		moderate
C. Identify ambiguous activity	X	?									X	X	low-high
V. Nuclear Warhead Production Freeze													
A. Monitor shut-down of existing key nuclear component fabrication facilities	X	?						?		?	X		high
B. Detect ambiguous activity at additional facilities	X	?						?		?	X		low-moderate
C. Identify ambiguous activity at additional facilities	X	?						?		?	X	X	low-high
VI. Weapons-Grade Nuclear Materials Cutoff													
A. Monitor military nuclear materials production facilities	X	?									X		high moderate-high
B. Detect ambiguous activity at civilian nuclear facilities	X	?									X		low-moderate
C. Identify ambiguous activity	X	?									X	X	low-high

*Comprehensive freeze could include a ban on replacement of these systems from new production.

X° = *indirect* assistance in monitoring provision.

Source: C. Payne and T. Karas, Federation of American Scientists Public Interest Report 35, 6 (September, 1982).

prohibiting forces on the Great Lakes. Mutual trust has insured the functioning of this treaty for over 150 years, a significant accomplishment in terms of political alliances.

Verification provisions will also not be required if the violations will be obvious or if the consequences of violations unimportant (Perry 1977 p.1). As we shall see, the Atmospheric Test Ban Treaty of 1963 presents a good example of this condition. The scope of verification required in an agreement can also be reduced or potentially eliminated by creating formal and informal santions. If the political and economic consequences of being caught violating a treaty can be made significant, the incentive to cheat is greatly reduced (Ikle 1961). Thus conscious decisions to violate a treaty involve consideration of advantage gained by cheating, the consequences of being caught and the chances of being caught.

From these considerations we see that complete bans on a class of weapons require less sophistication in verification than numerical limits. The detection of one weapon at any time is an obvious violation of a complete ban. With numerical limits, problems of an accurate count without double counting can become difficult. Mobile weapons such as the cruise missile and weapons that can be confused with conventional weapons further complicate matters.

In an age when we talk about overkill capabilities of nuclear weapons, the issue of marginal violations of numerical limits seems to be of little significance. For example if both sides would be limited to 10,000 warheads, 100 more or less will not create a great threat. However, if both sides are limited to 200 warheads, the same difference of 100 warheads has great strategic significance.

Negotiations between the US and USSR do not occur in an atmosphere of trust. We see the level of mistrust in these quotes from high level officials on both sides:

> As president Regan noted in his radio address last month, Western restraint stands in stark contrast to the Soviet buildup in intermediate range nuclear forces... His efforts have regretably met with stonewalling... pressure tactics are, of course standard Soviet methods.
> - Kenneth Adelman, director ACDA (Adelman 1984)

> Thus the 1970's and early 1980's turned out to be the worst period of the cold war, marked by Soviet sponsered agression... and attempts to seperate the US from Western Europe, Japan, and China through the achievement and acknowledgement of Soviet nuclear hegemony.
> - Eugene Rostow, former directo ACDA (Rostow 1984)

> The imperialist US is the main threat to peace.
> - Andrei Gromyko, Soviet Foreign Minister (Time Feb. 13, 1984 p.16)

Note the confrontational language in these and other quotes by top level negotiators.

This mistrust clearly impacts negotiations on strategic arms limitations. There has been a strong political imperative to produce agreements that rely on a minimum of mutual trust and maximum confidence on NTMs to monitor compliance. (Talbott 1979 p.31). Even with provisions to avoid cheating both sides continue to accuse each other of cheating (Eagle-Beacon March 15, 1984; Cong. Quarterly Jan. 21, 1984 p.107). Additionally, charges are made of trying to gain advantage simply by the form of the treaty (Harris 1979).

The high level of mistrust which leads to such double-talk as defensive first strikes also carries into the realm of verification.* Some officials argue that not only do we need adequate verification, but also that we need to prepare for the possibility of a strategic 'breakout' from existing parity in nuclear weapons. Fear of such technological first strikes leads both sides to march directly in the direction of creating their own technical advantage. Thus we see arms growth continuing in qualitative (technological) realms while being limited in sheer quantitative (numerical) terms.

While verification monitors compliance with a treaty, it is argued that this is not going far enough. We must garner "information about the capability intent or fact of strategic breakout from the rough parity of thermonuclear capabilities that is expected to deter war between the United States and Soviet Union" (Harris 1979 p.1).

With the complex technologies involved in researching, developing, and building a new weapons system, minimal lead times of five to seven years occur from the start of research untill first production (Fritzel 1984 p.69). Additional problems with funding increase the time even more. The missile-X (MX) program has been developing for over a decade and has yet to deploy an operational weapon. Because of this time delay, both sides continue to research systems limited by treaty 'just in case'. For example, consider recent

*We hope that this doubletalk is the result of fear and not of self interest, propoganda, or attempts to garner military contracts and funding.

disclosures about space based anti-ballistic missile (ABM) systems which have been researched over the ten years since the signing of the ABM treaty in 1974. The impetus for such research not only comes from fears about a technological advance giving the opponent a clear superiority, but also from fears that a marginal technological advance will be used to exert political force (Talbott 1979 p.71). John Foster first advanced these fears of breakout when he was director of Research and Engineering in the DoD (Kinter 1973 p.117).

The verification measures required in a given agreement are influenced by the level of trust between the signatories, the advantage gained by cheating, the consequences of being caught violating the treaty, and ease in detecting violations. Thus verification measures are a function of these four broad categories under which many other details fit. To visualize this we write verification as a function of these items:

Verification=V(trust, advantage, sanctions, detection).

<u>History</u>

We shall now undertake a brief review of the history of negotiations concerning nuclear weapons. This shall not be a complete history of negotiations, rather illustrative examples will be presented to demonstrate analyzing issues of verification.

The first proposal for limiting nuclear weapons occurred in 1946. At this time only the US possessed atomic weapons and this stockpile was small by today's standards. In 1946 at the first meeting of the United Nations General Assembly, the UN Atomic Energy Commission was created and charged with the elimination of all major weapons of mass destruction, including atomic bombs. In the US a committee of scientists and statesmen formed to discuss this issue. Physicist J. R. Oppenheimer conceived a radical proposal which became known as the Baruch Plan, after Bernard Baruch, the financeer who presented it to the UN. This committee saw the unprecedented power of atomic weapons and the unique chance of dealing with them before any momentum for their production started. their report said:

> It may seem too idealistic. It seems time we endeavor to bring some of our expressed ideals into being.
> It may seem too radical, too advanced, too much beyond human experience. All of these terms apply with peculiar fitness to the atomic bomb. In considering the plan ... one should ask one-self, 'What are the alternatives'? We have, and we find no tolerable answer.
> (Greb and Johnson 1983 p.248)

The plan called for establishment of an international nuclear developement authority which would control atomic energy activities and establish inspection procedures. Upon creation of this body, the US would dismantle its bombs.

The Soviet reply came quickly and called for immediate destruction of all atomic bombs before discussion of inspection and control could begin. At this point the negotiations broke down. While this seemed to be the fundamental difference that blocked the Baruch Plan, a further look reveals that perhaps other factors were also involved.

Baruch pushed for and received an important addition to the proposal, which would exempt UN Security Council veto power from atomic energy control matters (Craig 1984 p.4-11). This presented a great political threat to the Soviets who stood alone against the West at this time. With this provision they would have no way of stopping on sight inspection on ambigious matters. In the Russian's eyes this presented an opportunity for Western control of the monitoring body to accomplish espionage tasks (Bernstein 1983). It is possible that the fear of such political helplessness formed part of the original Soviet objection to the Baruch Plan. Thus they presented a counterproposal which they knew would be rejected by the United States.

Another proposal presented one month after the bombing of Hiroshima and Nagisaki has recently come to light. The plan never got further than Harry Truman and his cabinet. Nevertheless it contained a bold and unique approach to arms limitations that has yet to be seriously reconsidered. Secratary of War Henry Stimson presented the idea that "when the Soviets acquired the bombs- whether it be 4 or 20 years- was less important than the superpowers having a peaceful cooperative relationship when they did" (Greb and Johnson 1983 p.248). His plan additionally included the idea that negotiations should be between the US (possibly the UK) and the USSR to avoid overwhelming the Russians with fears of Western dominance. As we see, this plan involved the concept of fostering mutual trust as means for reducing the complications of arms limitation treaties. Unfortunately, the momentum of the cold war soon picked up and this unique opportunity was lost. Perhaps today we should ask ourselves how we might re-implement this approach in light of the experiences gained from the process of detente.

The cold war effectively blocked significant arms talks until the mid 1950's when the fallout from atmospheric nuclear weapons tests created a global outcry for cessation of such tests. In 1958 a conference of experts concluded that atmospheric nuclear explosions and most underground tests could be detected effectively at long distances (Greb and Heckrotte 1983 p.218). Note that this was before the advent of satellite reconnaissance.

In the fall of 1961, after several years of discussion, negotiations on a comprehensive test ban fell through over the issue of on sight verification. At this time plans had already been well established for an enforcement group having a staff of 5000 and an annual budget of $50 million (Craig 1984 p.4-19).

In 1962 pressure from the Eighteen Nation Disarmament Conference (ENDC) intensified. After proposal of a limited test ban treaty (LTBT), negotiations were completed in only ten days. With international fear over atmospheric tests quieted, the pressure for a comprehensive test ban treaty abated. Except for non-signers such as China, the LTBT has remained effective for over twenty years, which seems to be quite an accomplishment. The ease of detecting the characteristic double flash and X-ray flux of nuclear explosions in the atmosphere make violations of this treaty difficult to hide.

Another major factor in the sucess of the LTBT is that it accomplishes little more than calming public fears of fall-out. There would be no advantage gained by any nation by cheating on this treaty. Underground tests have continued at an amazing pace. There have been over 700 underground nuclear explosions since the signing of the LTBT and testing continues at a rate of about 15 per year in the US and 22 per year in the USSR (SIPRI 1980 p.359). Thus we see that devel-opement of new weapons and confidence testing of old bombs is not limited by the Limited Test Ban.

Minimal advantage would be gained by atmospheric tests. only additional information on electro-magnetic pulse (EMP) and exoatmospheric ABM weapons are limited by this treaty. We see that one reason for the sucess of the LTBT is the lack of advantage gained in violating the treaty.

While on sight inspection remains the publically stated hinderence to a comprehensive test ban (CTBT), there is little reason to think that even with effective verification of under-ground tests and allowances for OSI a CTBT would be accepted by either the US or USSR. The Threshold Test Ban Treaty (TTBT) of 1974 limited tests to 150 kilotons but still does not effect testing procedures greatly. It did significantly accomplish a sharing of information on tests. The first agreed step in bilateral arms treaties going beyond national technical means.

Defense experts and research scientists in the US have continually maintained that testing must continue in order to retain confidence in weapons systems. Additionally they argue that we will lose our stock of engineers trained and experienced with nuclear weapons (Greb and Heckrotte 1983 pp.225-226). From this viewpoint we see that the consequences of getting away with cheating under a comprehensive test ban would be considered substantial by the defense community. Thus groups such as the Joint Chiefs of Staff, the Department of Energy, and Los Alamos labortory can be expected to fight any proposed CTBT. In the case of these negotiations it may well be that verification issues are being used to justify political will.

Another treaty which has so far stood the test of time is the Anti-ballistic Missile Treaty of the SALT I agreement of 1974. This created a limit of two missile defense systems (later reduced to one) in both the US and USSR. While the US has charged the Soviets of testing radar that would violate the treaty, the agreement has stood firm until now. If we ask why, we see that once again the consequences of violating the treaty would be minimal and perhaps even economically detrimental.

As the original arguement against ABM systems goes, even if an effective system were set up by one side, the other side would presumably deploy a similar capability. This would fuel an even greater offensive arms race to overcome the defenses. Additionally other means of delivery (such as cruise missiles and bombers) would need to be defended against in order to ensure protection.

It is generally agreed that any missile defense would be extremely and uneffective. Stopping an incoming missile has been likened to hitting a bullet with another bullet (Garwin 1983 p.52). To ensure security an ABM must be nearly perfect. For instance, an ABM system that is 99% accurate would allow 20 to 30 warheads to get through in an all out attack of missiles. These 20 plus those delivered by other modes would still create substantial civilian damage. An interesting approach to missile defense first proposed by Richard Garwin involves throwing tons of dirt in front of incoming missiles, effectively destroying them (Garwin 1983 p.57). Dust struck by an incoming missile travelling at about 10^4 m/s will create more energy than chemical explosives (Hafemeister 1983 p.367).

The operational potential of such systems remains questionable since they cannot guarantee a high kill rate due to local environmental conditions and timing problems. We see that so far there has been little incentive to violate the ABM Treaty, thus verification and compliance have not been major issues. Despite this, fears of breakout have fueled continued research in the past ten years.

However, on March 23, 1983 President Regan in his 'star wars' speech proposed that we can develope capabilities to create effective deffenses in space in the next few decades. While prominant scientists still argue that this is unlikely, research is still quite secretive, so capabilities are not known. The arguement about fueling an offensive arms race remains. Despite these objections, the potential for an effective ABM system has led to suggestions of withdraw from this treaty. It is interesting to note that it appears that the ABM agreement will remain effective only as long as the advantage gained by abrogating it stays small.(Eagle-Beacon March 31,1984)

In recent years the SALT process has also been the forum for negotiations on strategic arms limitations. Here national technical means of gathering data were first officially sanctioned after years of unofficial acceptance. Article XII of the SALT I ABM Treaty and article V of the SALT I Interim Agreement on arms limitations codified the use of NTMs.

> 1. For the purpose of providing assurance of compliance with the provisions of this Treaty, each Party shall use national technical means of verification at its disposal in a manner consistent with generally recognized principles of international law.
> 2. Each Party undertakes not to interfere with the national technical means of verification of the other Party operating in accordance with paragraph 1 of this Article.
> 3. Each Party undertakes not to use deliberate concealment measures which impede verification by national technical means of compliance with the provisions of this Treaty. This obligation shall not require changes in current construction, assembly, conversion, or overhaul practices. (ACDA 1980 p.141)

The inclusion of these articles was a significant step in relations between the US and USSR. In addition to officially admitting to the role of intelligence, the agreement represented a willingness to compromise on both sides. The Soviets finally accepted the concept of 'open skies' first proposed by President Eisenhower in the 1950's. The US relinquished its calls for OSI, confirming that (at that time) modern NTMs could be more reliable and in fact superior to on sight inspection (SIPRI 1976 p.29).

Policy

In order to look more closely at SALT agreements limiting actual weapons systems we need to understand some of the strategic policies of the US and USSR. It is not always clear what actual US policy is and it is even less clear what strategic policies the USSR abides by. Additionally, perceptions of the President, the DoD, and the ACDA about the role of nuclear weapons do not always coincide. Note the following statements of policy:

> The paramount goal is to make war less likely, and above all, to avoid nuclear war. Of course, US arms control policy pursues other objectives as well: to reduce destructiveness of wars when wars do occur and to reduce the expenditure of human and economic resources for military preparations.
> -ACDA policy statement (Stukel 1978 p.5)

> The American nuclear arsenal has been planned and built as a deterrent against agression, all that American deterance requires is a convincing second strike nuclear capability...that is capacity to inflict unacceptable damage if our vital interests are attacked.
> -Eugene Rostow, former director ACDA (Arkin 1983 p.9)

> To keep peace, we and our allies must be strong enough to convince any potential agressor that war could bring only disaster...Deterance is essential to approach peace and protect our way of life.
> -President Regan (Cong. Quarterly 1984 p.98)

There are subtle differnces in perceived role of deterance, war fighting capabilities, etc. among high level officials.

The publically stated US policy of deterance has rested for years on the concept of mutually assured destruction (MAD).

This policy of massive retaliation assumes that the enemy will be deterred from attacking if the cost of retaliation would be the destruction of the attacker as a civilized nation. In 1962, then Secratary of State Robert McNamara put the level of adequate destruction as one-fourth the Soviet population and one-half of its industrial base. The accepted level has hovered around these values ever since (Hoeber 1981 p.46).

It seems that a policy consisting solely of MAD would require little need for verification since there could be great flexibility in numbers without presenting a significant threat. All that MAD requires is a credible second strike capability of several hundred deliverable nuclear bombs. Submarines and aircraft easily accomplish this. Even questions about vulnerability of the third leg of the strategic triad, intercontinental ballistic missiles (ICBMs) are hard to substantiate (Bunn 1983). The Scowcroft Commission report eliminated the myth of the window of vulnerability. If a policy consisting solely of MAD were followed, the consequences of treaty violation would be unimportant.

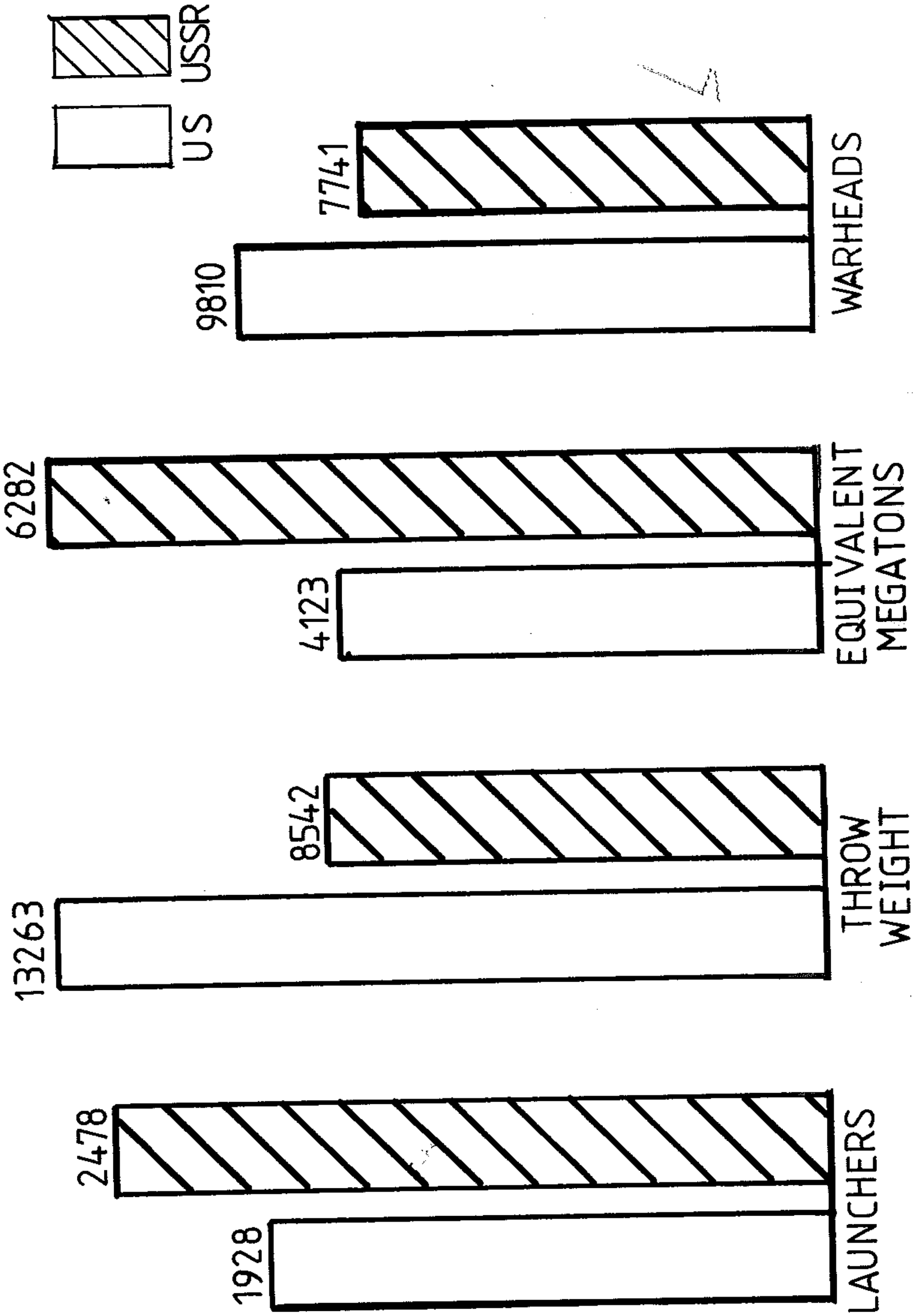
The US Department of Defense's Single Integrated Operational Plans (SIOPs) have reflected a policy of counterforce since the early 1960's (Craig 1984 p.9-7). Counterforce involves the targetting of military installations such as missile silos, command centers and air bases. The US policy recently has been reflected by terms such as flexibility, limited war fighting capability, protracted wars, prevailing in nuclear wars and nuclear use theories (NUTS). Such policies make it much more important for the US to limit the numbers of Soviet nuclear weapons and to be able to be insured that they are maintaining the limits. The Soviets most likely have similar goals. In this context, military verification of exact capabilities regardless of verification for treaties is important. In this we see that perhaps arms limitations talks can be more flexible than just discussing numerical limits.

A critical question faced in negotiations is what to limit. For a given weapons system there are several methods of counting who has what. Because of their speed of delivery and counterforce capability, ICBMs become the focus of many negotiations. A simple comparison of figures for US and USSR ICBMs in 1983 demonstrates the importance of this fact. Figure 1 counts ICBMs by four different methods. It is easy to see how these figures can be used to argue from just about any political viewpoint. These graphs demonstrate the importance for policymakers and average citizens to gain deeper understanding of the capabilities of weapons and the methods for counting them.

Counting

It is interesting to note that by attempting to more accurately record the effectiveness of a weapon, the number of unknowns which must be verified also increases. This suggests that there might be a tendency for a decrease in our trust in a measure of verification as the ability to measure the capabilities of the weapon increases. At this point,

Figure 1



data from Schroeer 1983

scientists have a fairly high trust in the abilities of many sophisticated systems to verify qualities and quantities of weapons. However, this was not always the case, SALT I did not limit bombers and submarines bacause of verification issues. With the introduction of cruise missiles, other smaller strategic systems, and the improvement of bombers, verification tends to rely increasingly on externally observable distinguishing features (EODFs) and functionally related observable differences (FRODs) for verification. These measures must be established by treaty and require trust that the other side will follow such measures.

Even with assurances from technology about the ability to verify qualities, the perceptions of policymakers must be taken into account.* A simpler and more easily visualized verification scheme may tend to stand a better chance of surviving the political hacksaw.

An examination of measures for counting ICBMs reveals a nesting of additional factors to measure as representations of the missile's capabilities gets progressively better. While this is intuitively obvious, a more detailed examination will reveal much about counting measures and structures underlying verification. Measurement of the numbers of launchers, numbers of reentry vehicles, total equivalent megatonnage (EMT), circular error probable (CEP), and kill-factor will be considered in turn. Each measurement requires evaluating factors

*A review of the Congressional Quarterly, Department of State Bulletin, newspapers and other sources clearly reveals the questions of policymakers about various schemes.

involved in all previous counts plus additional qualities to verify. This examination will not detail all the intracacies of verification procedures. It is important to understand enough of the technology to evaluate basic structures without getting bogged down by too many details.

Counting the number of launchers, or silos, is reletively easy as long as mobile missiles are not deployed. The count can be easily accomplished using satellite reconnaissance. This count can be checked at any point in time. However, many modern missiles have multiple independently targeted reentry vehicles (MIRVs) with from 3 to 14 seperate warheads on one missile. Several smaller bombs have more destructive power than one large bomb of equivalent megatonnage. Thus we propose that counting reentry vehicles might provide a better representation of capabilities.

A count of reentry vehicles becomes more complex since it not only involves the count of silos, but also keeping track of what is in the silos and verifying the number of RVs on the type of missile in the silo. Therefore, we must add monitoring missile tests and putting missiles in silos in order to keep count of reentry vehicles. Importantly, this involves continuous monitoring over time. Of course, such counts are routinely done.

While verification of the number of missiles is relatively easy, reliable verification of reentry vehicles has required additional treaty measures and still has encountered problems. In the mid 1970's the USSR built 30 new missile silos for MIRVed SS-19s close to 60 existing silos for single warhead SS-11s at the missile fields near Derazhyna and Pervomaisk. These silos outwardly appear identical. This became known among US negotiators as the D&P problem (in part because they encountered difficulty in pronouncing the names of the nearby towns). The problem was fear that the Soviets could somehow sneak new SS-19s into the old SS-11 holes without being detected. The US also had a similar problem near Malstrom Montana when it built shelters around minuteman silos to protect workers, who were upgrading the silo's hardness, from winter snowstorms. The Soviets feared that the US was replacing the single warhead minuteman IIs with the MIRVed minuteman IIIs.

Both these problems were addressed in the SALT II Treaty with additional details to ensure that verification can continue unhindered. One of these establishes that once a missile is tested with MIRVs, all missiles of that type will be considered to be MIRVed (Article II,paragraph 5, 2nd agreed statement). While rules like this are valuable verification tools, they also give additional incentive to upgrade systems to maximum limits. This is done to avoid being 'taken advantage of' in treaty limits.

SALT I established a Standing Consultative Committee (SCC) to meet regularly to discuss ambiguities regarding compliance with the treaty. The role of the SCC was expanded in SALT II. As more weapons systems are developed and dealt with in future arms treaties bodies similar to the SCC will most likely need to continue to expand to deal with more and more details.

Another assymetry in arsenals which might be considered is the size of warheads. This is measured in terms of tons of TNT, so 1 kiloton has the power of 1000 tons of chemical explosives. Some nuclear bombs are 'small', several kilotons, which is less than half the size of the bombs dropped on Japan. The largest deployed bombs have around 10 megatons of explosive power, 500 times the size of the Hiroshima bomb. Thus keeping track of yields might provide a good measure of the strength of nuclear forces. The peak overpressure (blast pressure) of a nuclear bomb scales approximately as the cube root of the yield, and the area destroyed depends upon the square of the distance from the bomb. By defining the equivalent megatonnage to be yield to the 2/3 power, destructive power of nuclear bombs can be compared directly. That is:

Equivalent Megatonnage (EMT)=Yield$^{2/3}$.

While limiting destructive power might seem to be a good measure for disarmament agreements, it would be difficult to verify with any degree of confidence. Additionally, while EMT may be useful for evaluating counterforce missiles, in other areas such as battlefield weapons, bigger is not better. The move from counting reentry vehicles to yield is a step from quantitative measures to more qualitative counts. Here we see the advantage gained by more accurately describing the strength of an arsenal is traded for greater uncertainty in the validity of the count.

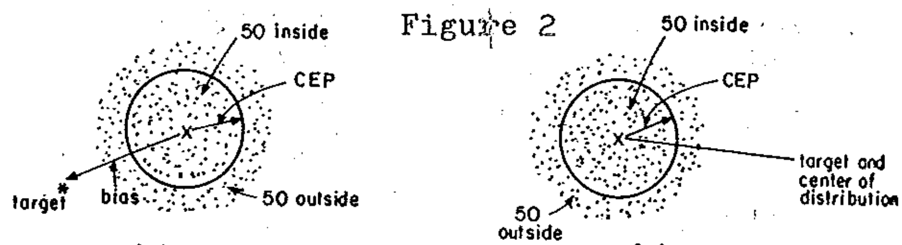
Two further measures which become important in discussions of counterforce weaponsare circular error probable (CEP) and kill factor (K-factor). CEP is a measure of the precision of a missile. It is the radius within which 50% of the missiles fired at a target would be expected to fall if fired at the same spot (see fig.2). Using the expectation for a single missile fired at a target landing within a given radius CEP is found to be slightly larger than the circular normal standard deviation (σ). This relationship is:

$$CEP=1.17\sigma.$$

From this we see that CEP is determined by monitoring test flight of missiles and how far they land from the intended target. Here monitoring the radio signals (telemetry) sent by a missile during a test becomes important. Powerful recievers have been developed to ferret such information, but these are useless unless the signals can be interpreted. So measuring CEP involves another task and SALT must provide provisions halting the encryption of telemetric data important for verification of treaties (SALT II, Article XV, Paragraph 3, 2nd Common Understanding).

While CEP measures the precision of a missile, neither side can be sure of its accuracy. Precision measures how close a missile can be expected to land to a given point, while accuracy measures how close that point is to the intended target. Bias may effect the accuracy of a missile. Figure 2 shows these properties (Tsispis 1983 p.140).

Figure 2



bias   no bias

Missiles have always been tested on east-west paths, while in use they would fly over the north pole. Abnormalities in the earth's gravitational field and magnetic field must be accounted for in missile flight programs (Hoag 1970). Without tests over the pole no one can be sure if these corrections are accurate.

Until recently the USSR has built large inprecise missiles, while the US has produced smaller more precise ones. Both accomplish the same mission. Thus a count involving both yield and precision would be useful. The probability that a missile will destroy a target of a given hardness (H) is given by the following equation (Tsispis 1978).

$$\text{Kill Probability} = 1-\exp(-Y^{2/3}/(CEP)^2/H^{2/3}/.22).$$

From this we define the kill factor K:

$$K=\text{Yield}^{2/3}/(CEP)^2=EMT/(CEP)^2 .$$

The K-factor provides a good measure of the counterforce ability of a missile giving kill probability as:

$$\text{Kill Probability} = 1-\exp(K/(.22H^{2/3})).$$

The value for K holds only for values less than approximately 100 (depending on soil conditions), due to the fact that for small CEP or large yield the bomb crater will always encircle the target. Only the newer minuteman III and SS-19s have K larger than 100.

Combining data required for measuring total K-factor of all deployed ICBMs four basic qualities/quantities must be observed. The missile silos must be counted, MIRVing needs to be considered, yields evaluated, and CEP monitored.

Note the nesting of qualities/quanties to be counted in the summary of counting methods for ICBMs (Table 2).

Table 2

Counting Measures	Factors
Launchers	Count Silos
Reentry Vehicles	Monitor Silos, Count MIRVs
Yield	Monitor Silos, Count MIRVs Determine Yields
K-factor	Monitor Silos, Count MIRVs Determine Yields Monitor CEP

Seeing that some relationship exists between the level of verification and its value in measuring the capabilities of a weapons system, it will be useful to develope an image to enhance understanding of what has been said. Consider the set of potential agreements and their value to be a surface determined by the systems that are limited (the content of the treaty) and the means of verification. However, since these two factors are interrelated, rational negotiable treaties are constrained to a curve on this surface. Arms negotiations must be seen in this light. Movement along the curve can be produced by changes in either qualitative-quantitative limits or in verification methods, however both cannot be freely changed, as movement must be constrained to a curve of potential agreements.

As we have seen, verification is a function of several factors, so the constraint curve on our hypothetical surface can be shifted by factors such as level of trust, sanctions for being caught violating the treaty, or the advantage gained by getting away with cheating on the treaty. The second of these can be potentially changed in the treaty itself, the third depends on technological factors and the first on human relations and goodwill. We see that innovative approaches to negotiations need to consider these factors.

The Race?

Having examined various methods of counting, it will perhaps be useful to see what they reveal when applied to arms growth over the past few years. Perceptions about arms growth vary widely. As we shall see, simply asking whether or not there is an arms race falls far short of being a complete question. The context of what counting measures are being considered is extremely important. We would laugh at two people arguing 'whether or not the box is four high'. Four what; inches, miles, meters, bananas? The person claiming that the box is less than four miles high and the one who is sure that it is more than four inches high can both be right. However, unless they both specify the units they are using,the arguement will be a nonsensical comedy. The same holds for discussions on the arms race. Consider this when next listening to the President and Freeze advocates arguing their points of view.

In order to see the effect various counting methods have on questions about the arms race, the growth of strategic missiles over the past fifteen years will be examined with several different counting methods. This study will only examine submarine launched ballistic missiles (SLBMs) and intercontinental ballistic missiles (ICBMs) deployed by the US and USSR. These weapons have been the focus of many negotiations over the past years. They represent a category which is unique in their ability to destroy hardened targets (counterforce ability) such as silos and in their very quick delivery time of less than 30 minutes over intercontinental distances.

There are advantages and disadvantages to looking at only one such type of weapons as opposed to nuclear weapons as a whole. Over time different types of delivery modes can receive varying amounts of emphasis. For instance, recent trends appear to be involving deployment of large numbers of cruise missiles and developing of space weapons and defense systems. Thus, by looking at only one type, some of the overall picture of the arms race is lost. Additionally, assymetries between the forces of the US and the USSR create different emphsis on production. However, over the period studied here (1967-1982), missiles were of vital importance to both sides so that the bias due to assymetries will be minimized.

The advantages of looking at just missiles involve the fact that the technologies, research, developement, and production are confined to a smaller sphere than by considering nuclear weapons as a whole. By doing this only one sector of the military industrial complex will be considered. In examining the question of an arms race the arsenals of the US and USSR will not be compared. The first question which must be asked is what sort of 'race' there is, not 'who is winning'. Lewis F. Richardson developed a mathematical model to describe a modern arms race (Richardson 1960). Given two nations, call them R and A, their growth of arms expenditures (measured in some appropriate way) over time is given by dR/dt and dA/dt respectively. Richardson started with some simple assumptions and came up with a set of differential equations to describe an arms race. These are:

$$dR/dt = cA - fR + j$$

$$dA/dt = dR - gA + l \ .$$

In these equations c and d represent defense coefficients indicating response to the other nation's buildup. Economic and political fatigue factors are indicated by the coefficients f and g. The constants j and l represent ambitions and grievences that are inherent regardless of hostile forces.

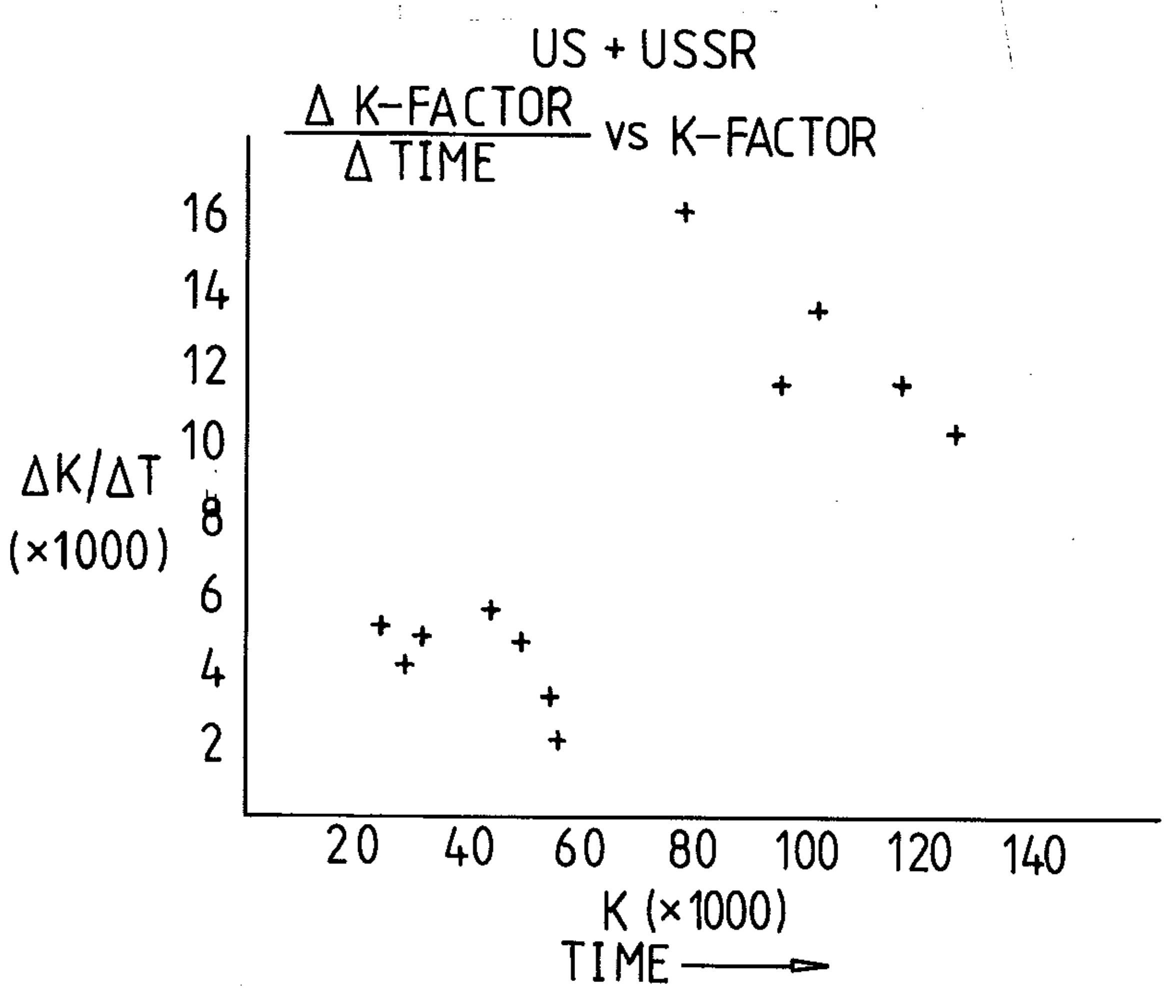
By assuming that modern production factors are roughly equal, Richardson set c=d and f=g. Then by adding the equations, the rate of change of the sum of the arsenals grows in proportion to this sum. That is,

$$d(R+A)/dt = \text{Linear Function of } (R+A).$$

Richardson showed that this described very nicely the arms race shortly before World War I. In present nuclear arsenals costs of production do not give an accurate picture of strength, so Richardson's equations have been employed using other measures of overall nuclear strength. In these cases growth of total nuclear warheads (Craig 1983) and NATO-Warsaw pact forces (Schrodt 1982) seem to fit this model very nicely.

In order to see if growth in one sector only of nuclear production would fit Richardson's model the total K-factor of US and USSR counterforce missiles was used as a measure for these equations. The results are that in this given sector, under the assumptions given above, growth does not appear to be spiraling. Figure 3 below does not have a linear fit.

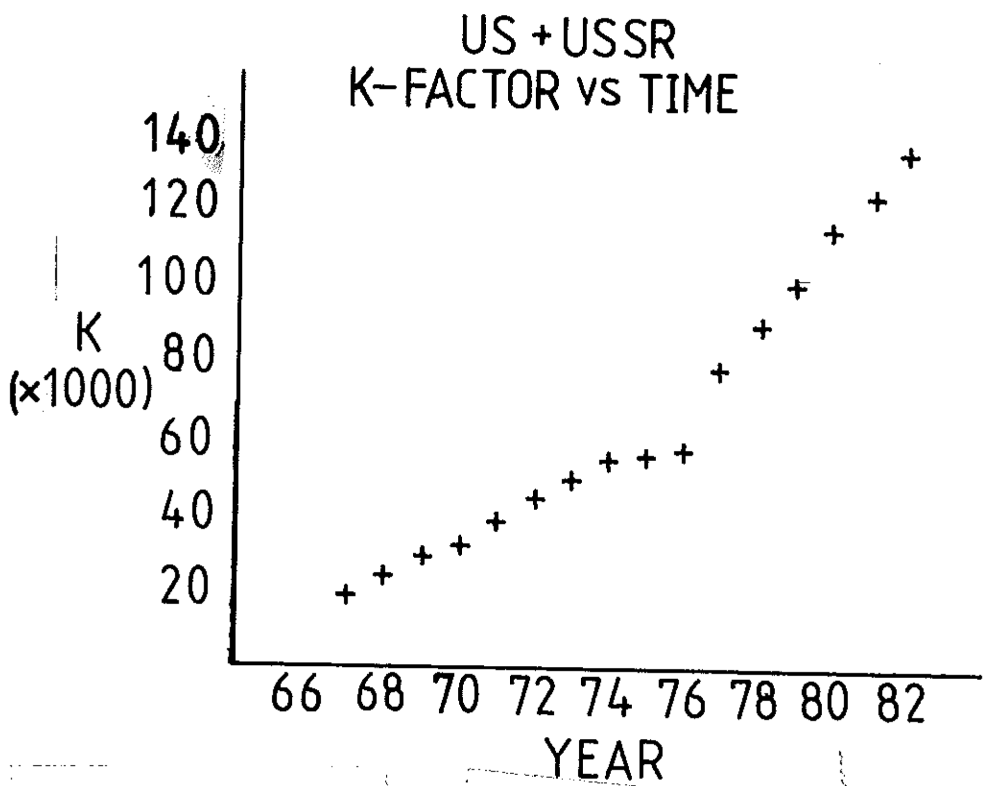
Figure 3



Simlarly, the graph of $\Delta RV/\Delta t$ did not turn out linear.

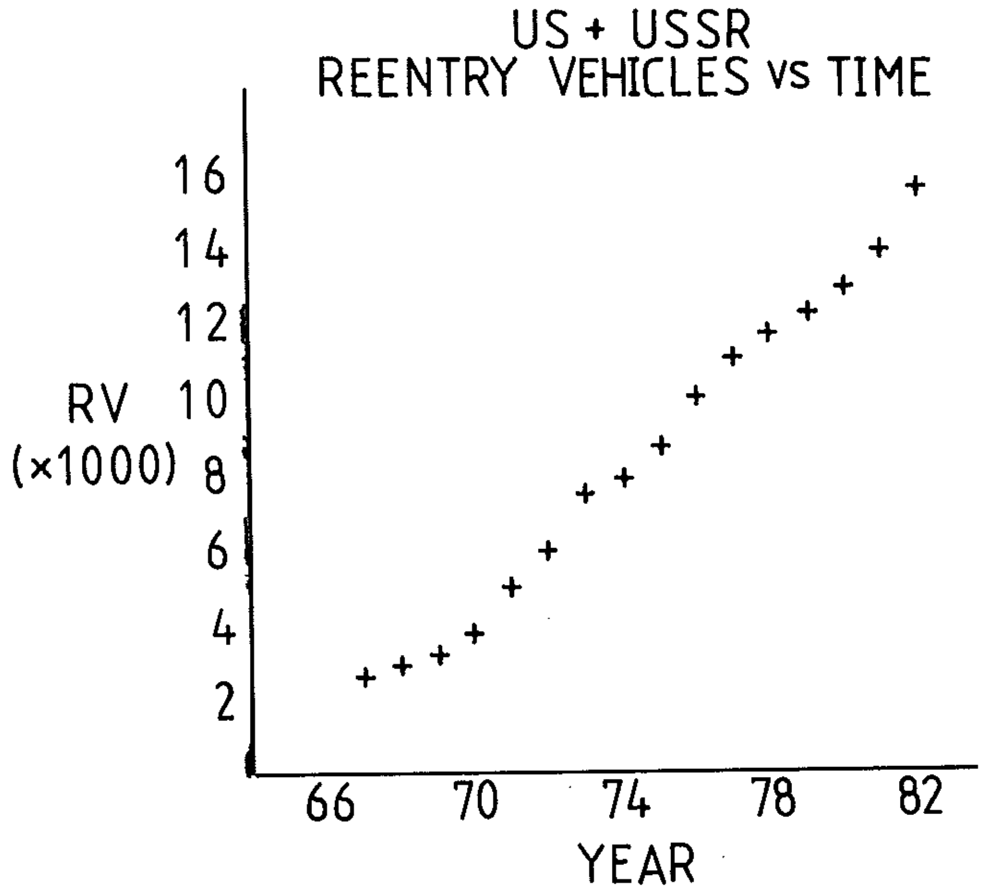
Seeking a more simple relation for the qualitative growth of missiles over the past fifteen years reveals a very steady arithmetic growth. This is seen in a graph of K-factor against time in figure 4.

Figure 4



The change in slope that occurs around 1978 represents the Soviet Union's deployment of missiles with accuracies similar to those that had been deployed by the US for many years. The pattern of growth for reentry vehicles shows the same arithmetic growth over time without the change in slope due to improved accuracies in 1978. This seen in figure 5 on page 35.

Figure 5

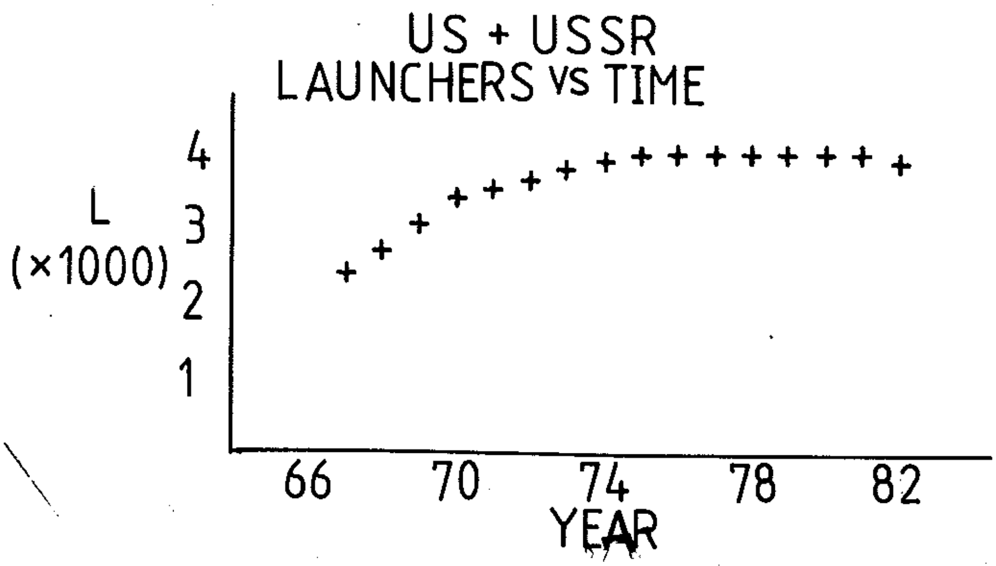


When we consider the SALT Treaties, the result that missile growth is not spiraling out of hand is not at all suprising. Figure 6 shows the situation of almost no growth in the number of launchers over time, in accordance with the SALT Treaties (p. 36).

These results do show that despite SALT limitations on the quantitative factors of missiles, arsenals have continued a slow and steady qualitative growth. There are no signs of this growth abating.

This arithmetic growth in K-factor and reentry vehicles

Figure 6



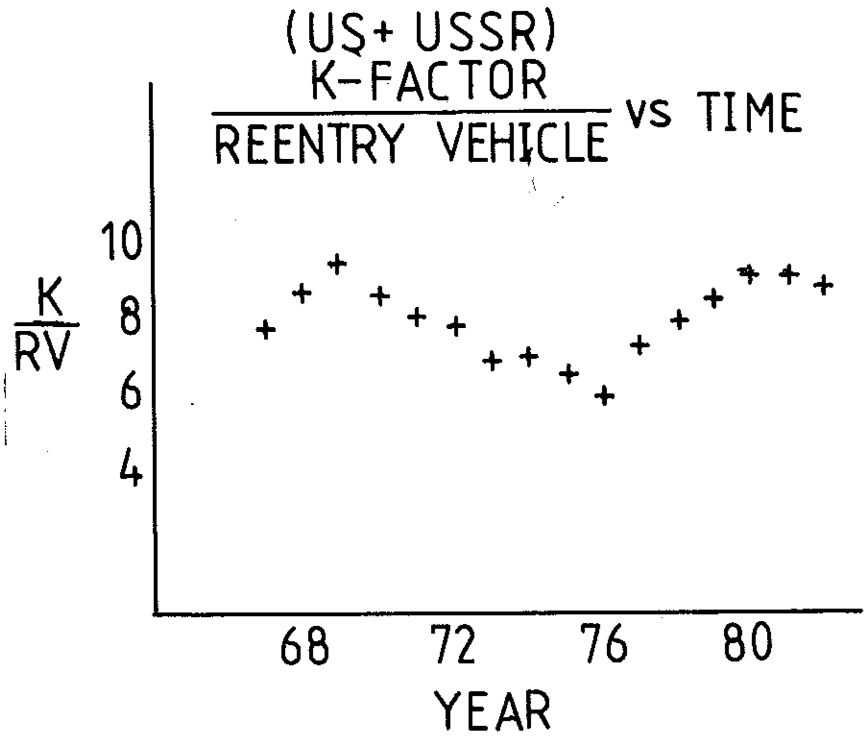
which seems uneffected by outside influences such as treaties and political situations provides evidence for the institutionalization of the missile producing sector of the military industrial complex. This seems reasonable when considering the long research and developement lead times and the effort required to set up production of missiles. Any changes in growth or responses to the 'enemy's' growth would take a long time to be assimilated into the massive system involved in the production of missiles.

We see that neither spiraling qualitative growth nor slowdowns can be expected to occur over short periods of less than a decade. In Richardson's equations this would indicate for one highly technological production sector the defense and fatigue coefficients are very small. Growth comes from constant ambitions and the sheer momentum created by the research and production processes. Arsenal strength changes that do occur apparently more quickly over time might be expected from changes in less technological systems which can more readily change production rates and from the introduction of new systems (that may or may not have taken a long time to develope).

We might guess that the introduction of the cruise missile will lead to several years of more rapid growth followed by a leveling as production processes become institutionalized. However, cruise missiles involve less sophisticated technologies than intercontinental missiles so their production rates might be more susceptable to outside influences. If this proves to be true, cruise missiles (and perhaps other new 'cheap' effective weapons) will throw new factors into arms negotiations. Overall arms growth will also continually be effected by the introduction of new weapons systems since technological can not and probably should not be limited.

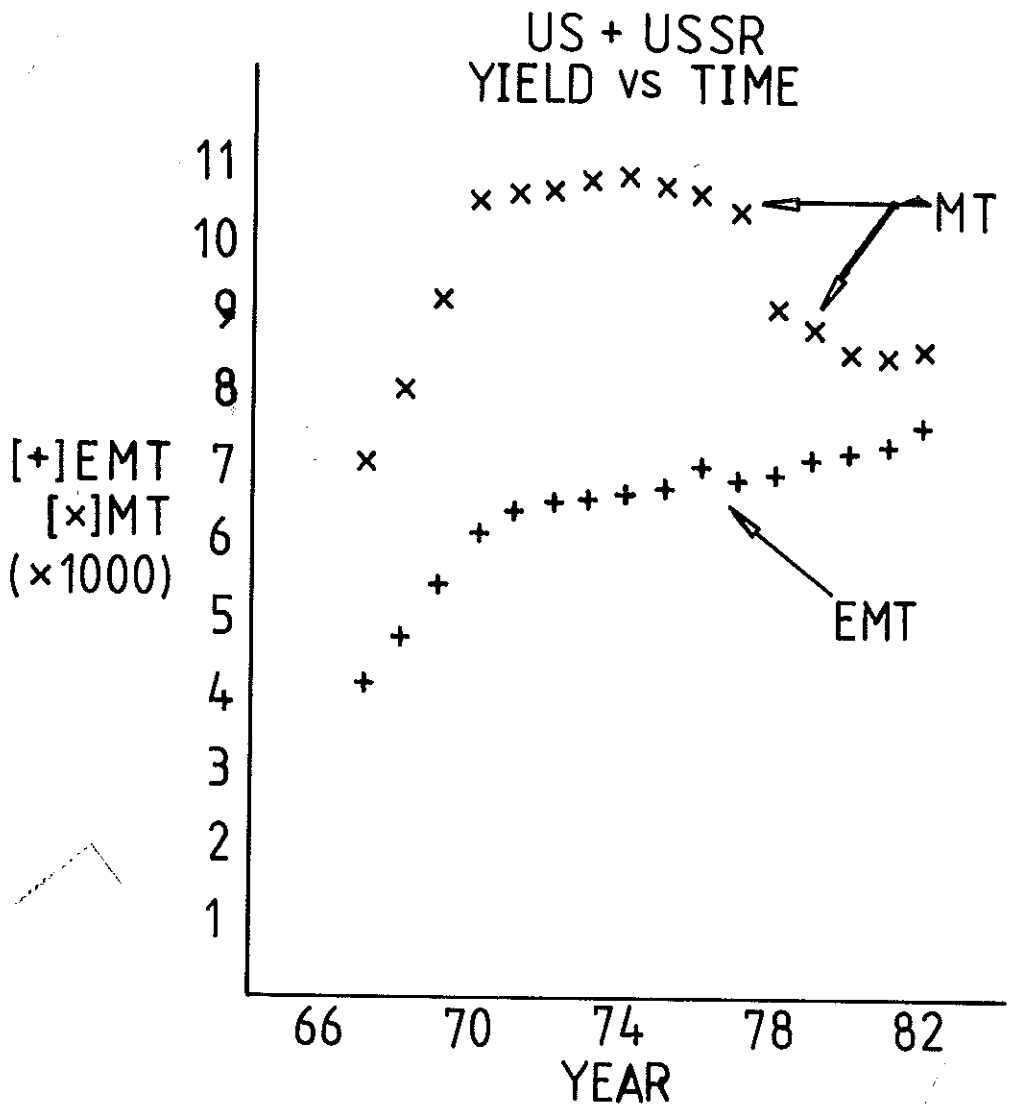
In order to examine the extent to which growth has been occurring solely in qualitative realms, the average K-factor per reentry vehicle was examined. Figure 7 (p. 38) reveals that growth has been occurring in both the number of MIRVed missiles and the precision of these missiles. Thus there are only fluctuations in the ratio of this qualitative factor to the quantitative factor over time rather than a clear increase or decrease.

Figure 7



Another measure comparing qualities to quantities is a comparison of total yield to total equivalent yield (destructive power). From this we see evidence of the trend towards replacing old large nuclear warheads with several smaller bombs. Because of the 2/3 power factor (see p.26) in equivalent megatonnage, several smaller bombs will have greater EMT than one large bomb of the same megatonnage. Figure 8 (p. 39) shows that while total megatonnage has dropped in the last years, the destructive power measured as equivalent yield has increased.

Figure 8


US + USSR
YIELD vs TIME
[+]EMT
[×]MT
(×1000)
11
10
9
8
7
6
5
4
3
2
1
MT
EMT
66
70
74
78
82
YEAR

Conclusions

We have seen that verification plays an important role in Strategic Arms Limitations Talks. Issues of verification can at times shape negotiations and treaties and at other times be shaped by the form of the treaty. Possible treaty outcomes need to be viewed in light of this constraining relationship. Technological and political factors reveal information about which consideration is dominant in a given set of negotiations.

Counting measures vary from quantitative to qualitative. A simple review of various measures supports the view that counts which provide a clearer measure of capabilities of an arsenal are more difficult to verify. Any discussion of the arms race must be couched in the context of counting measures.

Examining the growth of strategic missiles over the past fifteen years in light of various counting measures has revealed an arithmetic growth in more qualitative factors. This presents evidence that highly technological weapons systems function with little dependence upon treaties or political factors. Thus we see individual sectors of the military industrial complex producing slowly and methodically. In these areas the arms race is neither stopped nor spiraling out of hand.

APPENDIX I

ACRONYMS

ABM - anti-ballistic missile
ACDA - Arms Control and Disarmament Agency
CEP - circular error probable
CTBT - Comprehensive Test Ban Treaty
DoD - Department of Defense
EMP - electro-magnetic pulse
EMT - equivalent megatonnage
ENDC - Eighteen Nation Disarmament Conference
EODFs - externally observable distinguishing features
FRODs - functionally related observable differences
H - hardness
HUMINT - human intelligence
ICBM - intercontinental ballistic missile
K-factor - kill factor
LTBT - Limited Test Ban Treaty
MAD - mutually assured destruction
MIRV - multiple idependently targetted reentry vehicles
MT - megatonnage
NTM - national technical means
NUTS - nuclear use theories
OSI - on sight inspection
P_k - kill probability
RV - reentry vehicle
SALT - Strategic Arms Limitations Talks
SCC - Standing Consultative Committee
SLBM - submarine launched ballistic missile
TTBT - Threshold Test Ban Treaty
UK - United Kingdom
UN - United Nations
US - United States
USSR - Union of Soviet Socialist Republics

APPENDIX II

Graph Data

Source for data; SIPRI 1976, 1980, 1982

Year	Missile Launchers			Missile Yield		
	US	USSR	Total	US	USSR	Total
1967	1710	747	2457	2396	4667	7065
1968	1710	959	2669	2496	5449	7945
1969	1710	1355	3065	2596	6615	9210
1970	1710	1746	3456	2480	8098	10580
1971	1710	1887	3597	2436	8195	10630
1972	1710	1983	3693	2393	8291	10685
1973	1710	2111	3821	2348	8413	10760
1974	1710	2231	3941	2297	8523	10820
1975	1710	2287	3997	2167	8571	10740
1976	1710	2223	3933	2145	8527	10670
1977	1710	2338	4048	2026	8396	10420
1978	1710	2323	4033	2018	7166	9180
1979	1709	2337	4045	2018	6865	8880
1980	1628	2348	3976	2034	6468	8500
1981	1652	2348	4000	2060	6409	8470
1982	1572	2348	3920	2120	6500	8620

data (continued)

Year	Missile EMT			Reentry Vehicles		
	US	USSR	Total	US	USSR	Total
1967	2093	2189	4280	1710	747	2457
1968	2153	2593	4745	1710	959	2669
1969	2213	3245	5460	1710	1355	3065
1970	2225	4007	6230	1938	1746	3684
1971	2281	4127	6410	2138	1887	4825
1972	2327	4223	6550	3858	1986	5844
1973	2241	4364	6605	5210	2124	7334
1974	2226	4468	6695	5678	2228	7906
1975	2185	4550	6735	6410	2308	8718
1976	2195	4810	7005	6842	3160	10002
1977	2220	4635	6855	7130	3894	11024
1978	2220	4700	6920	7274	4393	11667
1979	2215	4900	7115	7274	4937	12211
1980	2200	5014	7215	7000	5920	12920
1981	2330	5014	7345	7032	6848	13880
1982	2320	5183	7505	6952	8390	15342

Year	K-factor (x 100)		
	US	USSR	Total
1967	150	33	183
1968	190	41	231
1969	229	56	285
1970	240	73	313
1971	302	79	381
1972	361	83	443
1973	404	88	492
1974	445	92	537
1975	459	96	555
1976	465	118	577
1977	472	319	791
1978	474	431	905
1979	474	550	1024
1980	516	657	1173
1981	597	657	1254
1982	657	721	1378

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