APPENDIX A

METHOD USED TO CALCULATE SSKP

The probability that a warhead will destroy a target is a function of reliability (the probability that the warhead will arrive at the target and detonate) and the Single Shot Kill Probability (SSKP--the probability that the arriving warhead will destroy the target). The SSKP of a warhead depends on the hardness of a target and on the warhead's yield and accuracy. Yield affects the SSKP because a weapon of higher yield produces, at any given radius from the blast, a higher peak overpressure (pressure above standard atmospheric pressure) and a longer period of high overpressures. Both a higher peak overpressure and a longer period of high overpressures increase the probability that a structure will suffer major structural damage from a blast. Better accuracy reduces the distance between the target and the blast.

The method used in this study to calculate the SSKP was developed by the Defense Nuclear Agency (DNA). That method employs an index of target hardness called a vulnerability or "V" number. The index is pegged to a reference yield of 20 kilotons (kt), which is a simple way to make the duration of the period of high overpressures a function of the peak overpressure generated by a blast. Thus, each target is given a V number based on the level of peak overpressure (generated by a 20-kt blast) at which the target has a 50 percent probability of suffering major structural damage.

Public statements by the Department of Defense on the hardness of targets, however, are given in terms of pounds per square inch (psi) of peak overpressure rather than in terms of a V number. The hardness (H) in pounds per square inch can be converted to a V number with the following formula: 1/

$$V = (5.485 \times \ln(H)) + 4.08$$

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1. This formula can be derived by inserting yield (Y=1,000 kt) and the k-factor (k=7) into the following set of formulas:

   1) $a = 1 - .1k$
   2) $b = .1k \times (20/Y)^{1/3}$

(continued)

This formula is based on the assumption that although the V number uses a reference yield of 20 kt, a reference yield of one megaton has been used for estimates of the hardness of Soviet silos measured in pounds per square inch. 2/ The formula is also based on the assumption that structures such as Soviet silos have a sensitivity to the duration of the period of high overpressures, as measured by an index called the "k-factor," of 7. 3/ A formula based on alternative assumptions can be derived from the set of formulas given in footnote 1. With the appropriate V number and k-factor, the probability that a weapon would destroy a target (that is, cause major structural damage) was calculated by using Continuous Read Only Memory (CROM) software developed by DNA. 4/ The CROM software was used in this study because it compensates for the duration of the period of high overpressure, allows calculations at high levels of target hardness such as 5,000 psi, and can be programmed to perform multiple calculations. Comparable results can also be obtained by using a circular slide rule (the "Damage Prediction Rule") developed and distributed by DNA.

There are several alternatives to the DNA CROM software and slide rule for calculating SSKP values. A circular slide rule is manufactured by the Rand Corporation titled the "Bomb Damage Effect Computer." It can calculate SSKP values for targets up to a hardness of 1,000 psi. Two formulas also have been developed to calculate SSKP values. 5/ In these formu-

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1. (continued)

3) $R = a + (b^2/2) + .5((2a+b^2)^2 - 4a^2)^{.5}$

4) $V' = (5.485 \times \ln(H)) - .63$

5) $V = V' - (5.485 \times \ln(R))$

See Maurice Mizrahi, "Appendix A: Hard-Target-Kill Methodology (Unclassified)," *Mobile Missile Mix* (Center for Naval Analysis, Study 1170, vol. 3, April 1982).

2. Information provided by the Defense Nuclear Agency.

3. The k-factor for hardened underground structures such as Soviet ICBM silos normally is between 7 and 8 (Defense Nuclear Agency).

4. Defense Nuclear Agency, *Nuclear Weapons Targeting, AP-550, CROM Al,* Report Number HTI-R-79-110, June 1, 1979 (Unclassified).

5. Both formulas are presented in detail in Lynn Davis and Warner Schilling, "All You Ever Wanted To Know About MIRV and ICBM Calculations But Were Not Cleared To Ask," *Journal of Conflict Resolution*, vol. XVII, no. 2 (June 1973). Given the assumptions made in this study (k-factor of 7 and reference yield of one megaton), these formulas give comparable results to the CROM A1 software when warhead yield is 100 kt. At significantly lower or higher yields, results can diverge substantially.

las, "Y" is the yield measured in megatons; "H" is the hardness of the target measured in pounds per square inch (psi); and "CEP" is the accuracy measured in nautical miles by the Circular Error Probable--the radius of a circle around a target such that there is a 50 percent probability that the warhead aimed at the target will detonate within or above the circle.

1) $SSKP = 1 - .5^{A}$ where $A = \dfrac{6Y^{2/3}}{H^{2/3}CEP^{2}}$

2) $SSKP = 1 - .5^{A}$ where $A = \dfrac{8.41Y^{2/3}}{H^{.7}CEP^{2}}$

The SSKP calculated using these different approaches can, under some assumptions, vary by 10 percent to 15 percent. Such variations should not be a major cause for concern, however, when placed in the context of uncertainty about other assumptions including weapon reliability, the yield and accuracy of warheads, the overpressure required to crush or deform particular structures, and the probability that a facility would be disabled by effects other than major structural damage.