# Appendix D

# Defense Requirements for Assured Survival

Opinion varies greatly on how much damage the United States could sustain from a Soviet nuclear attack and still survive. Opinion also differs on what is important in determining whether the United States has survived. Some believe that what matters is how well society would survive and reconstitute itself. Others argue that the nation will have survived if it recovers its superpower status and its economy in some specified number of years. Still others argue that survival is assured only if the number of casualties can confidently be kept below some "limited" number. However, within this group opinions differ on what that number is. Some believe that the nation can sustain 10 million casualties or more, while others believe that if the nation suffered hundreds of thousands of civilian deaths in a short period of time it would be a catastrophe without precedent, and the nation could certainly not be said to have survived. [1]

This appendix illustrates how the number of casualties might be related to defense capability if the Soviets were to attempt to maximize U.S. casualties. Most observers would probably agree that an extremely capable defense would be required to keep casualties low if the Soviets decided to attack in an effort to maximize casualties. Because of the great destructive power of nuclear weapons and the concentration of U.S. population in major urban areas, a small number of nuclear weapons detonating over populous areas would cause large numbers of casualties. Planners seeking a defense to assure survival would most likely make "defense conservative" estimates. They would give the offense a great benefit of the doubt and estimate the capability of their defense very conservatively in order to minimize the likelihood that casualties would exceed their expectations.

This appendix illustrates how such worst-case estimates of casualties might be made and how they would be related to defense capability. It is illustrative of an approach to the problem of determining requirements for assured survival. It is not a prediction of casualties that would result from an attack on the United States. Casualties need not be as high as shown here, and they might be considerably lower. We assume that the Soviets attack to maximize casualties and that no civil defense measures are taken. Different Soviet attack tactics, evacuation of cities, and preferential defense of the most heavily populated areas might all contribute to reducing casualties. On the other hand, long-term nuclear effects spreading far beyond the immediate blast area might increase casualties,

OTA does not predict either that the required defense levels are achievable or that they are not achievable.

This appendix presents a rather rudimentary calculation in order to illustrate the problem. We recognize that the results can be refined substantially by taking advantage of detailed, sophisticated information on population distribution, aimpoint uncertainties, and nuclear weapon effects.

It is assumed that since the United States has extremely capable defenses, the Soviets are denied the capability for a meaningful attack on U.S. military assets, and they hence concentrate their forces to produce the greatest number of casualties they can. A force of 9,000 RVs, roughly equal to the current Soviet force, is assumed. Each RV is assumed to have a 750 kiloton (kt) yield. For simplicity, the attacking weapons are all ballistic missile RVs and the defense is BMD only.

The basic scenario is as follows. The Soviets know about how capable the U.S. defense is. They prepare a list of aimpoints such that the first is the most densely populated part of the United States, the second is the second most densely populated part, and so on. They allocate their weapons against the most populous part of this list in a manner to be described and do not attack the rest of the United States.

To illustrate some of the uncertainties in this calculation, four cases have been examined. In two cases, the worst for the United States, the Soviets are assumed to know *exactly* how good the U.S. defense is, and they allocate their weapons to achieve an expected one weapon penetrating to each aimpoint. The number of aimpoints is equal to 9,000 (1-$P_k$, where $P_k$ is the probability that the

[1] Some people believe that even if many tens of millions of Americans died, society would remain intact (or rapidly reconstitute itself) and the nation would have survived. Others believe that society can be destroyed even if casualties are relatively low.

defense kills an RV attempting to penetrate it.' As a worst case, we assume that they hit each aimpoint. In actuality, some aimpoints would survive. In the other two cases, the Soviets only know roughly how good the defense is, so they target 100 RVs on each of 90 aimpoints. Their hits are distributed randomly among the aimpoints. In each case, they begin with the most populous aimpoint and allocate weapons in descending order until all their weapons are allocated.

For each of the two cases described in the preceding paragraph, we use two different kill criteria, for a total of four cases. In two of the cases, the Soviets distribute their weapons to produce 3 pounds per square inch (psi) overpressure over the entire area attacked. In the other two cases, they distribute their weapons to put 5 psi over the area attacked. We assume in each case that everyone living in the attacked area is killed. It is beyond the scope of this appendix to determine the minimum overpressure that would kill everyone subjected to it, although it seems likely that the answer is between 3 and 5 psi.[3] A 1978 ACDA report[4] says that 3 to 5 psi would cause total burn out in urban areas. A 1979 OTA report[5] estimated that most of those exposed to 5 psi would be killed immediately or seriously wounded, and that half of those exposed to 2 to 5 psi would be killed or seriously wounded. Many of the wounded would eventually die for lack of care. A 750 kt weapon detonated at 2,000 feet above the ground would produce 5 psi or more overpressure over about 24 square miles and 3 psi or more over 50 square miles.

In order to understand how U.S. population is distributed among the most populous parts of the nation we examined both the most populous cities and the most densely populated counties and cities. These are listed in tables D-1 and D-2, respectively. The distributions of cumulative population as a function of total area occupied obtained from these were reasonably similar, despite the fact that there were many areas that appeared on one list but not on the other.

Figure D-1 shows the number of people living in the most populous parts of the United States. It is arrived at by summing down tables D-1 and D-2 in rank order, beginning with number 1. If the Soviets wanted to maximize casualties, they would begin by allocating their weapons against the most heavily populated areas, and work their way up the cumulative curves until they ran out of weapons. Figure D-2 repeats figure D-1, but also shows the number of detonations required to produce 5 psi over a given area and the number of weapons required to produce 3 psi. For example, 40 deto-

[2] $(1-P_k)$ is the probability that an RV gets through the defense, so 9,000 $(1-P_k)$ is the number of RVs they expect to get through the defense. Hence, they aim at that number of aimpoints. An actual calculation of the number of aimpoints would probably be more sophisticated than this, since some of the intended aimpoints will receive more than one detonation while others will be successfully defended. The worst they can do, from the U.S. perspective, is to hit each intended aimpoint.

[3] Some maintain that in either case the number of casualties is likely to exceed the population of the area attacked, because effects such as fallout and groundwater contamination, as well as destruction of vital services, would kill far beyond the blast area.

[4] "An Analysis of Civil Defense in Nuclear War" December 1978.

[5] U.S. Congress, Office of Technology Assessment, *The Effects of Nuclear War* (Washington, DC: U.S. Government Printing Office, May 1979), OTA-NS-89

**Table D-1.—Population, Area, and Population Density of the Most Populous U.S. Cities**

| Rank | City | Population (thousands) | Area (square miles) | Population per square mile |
|---|---|---|---|---|
| 1 | New York | 7,072 | 301.5 | 23,455 |
| 2 | Chicago | 3,005 | 228.1 | 13,174 |
| 3 | Los Angeles | 2,967 | 464.7 | 6,384 |
| 4 | Philadelphia | 1,688 | 136.0 | 12,413 |
| 5 | Houston | 1,595 | 556.4 | 2,867 |
| 6 | Detroit | 1,203 | 135,6 | 8,874 |
| 7 | Dallas | 904 | 333.0 | 2,715 |
| 8 | **San Diego** | **876** | **320.0** | **2,736** |
| 9 | **Phoenix** | **790** | **324.0** | **2,437** |
| 10 | **Baltimore** | **787** | **80.3** | **9,798** |
| 11 | **San Antonio** | **786** | **262.7** | **2,992** |
| 12 | **Indianapolis** | **701** | **352.0** | **1,991** |
| 13 | **San Francisco** | **679** | **46.4** | **14,633** |
| 14 | **Memphis** | **646** | **264.1** | **2,447** |
| 15 | **Washington** | **638** | **62.7** | **10,181** |

SOURCE: Statistical Abstract of the United States, 1984. Department of Commerce, Bureau of the Census Populations are based on the 1980census.

**Table D.2.—The Most Densely Populated Counties and Independent Cities in the United Statess**

| Rank | Name | Population per square mile | Area (square miles) | Population (thousands) |
|---|---|---|---|---|
| 1 | New York, NY. | 64,395 | 22 | 1,428 |
| 2 | Kings, NY | 31,762 | 70 | 2,231 |
| 3 | Bronx, NY | 28,006 | 42 | 1,169 |
| 4 | Queens, NY | 17,411 | 109 | 1,891 |
| 5 | San Francisco, CA | 14,636 | 46 | 679 |
| 6 | Philadelphia, PA | 12,413 | 136 | 1,688 |
| 7 | Hudson, NJ | 11,993 | 46 | 557 |
| 8 | Suffolk, MA. | 11,472 | 57 | 650 |
| 9 | Washington, DC | 10,181 | 63 | 638 |
| 10 | Baltimore, MD (city) | 9,793 | 80 | 787 |
| 11 | St. Louis, MO (city) | 7,379 | 61 | 453 |
| 12 | Alexandria, VA (city) | 6,867 | 15 | 103 |
| 13 | Essex, NJ | 6,696 | 127 | 851 |
| 14 | Richmond, NY | 5,995 | 59 | 352 |
| 15 | Arlington, VA | 5,878 | 26 | 153 |
| 16 | Cook, IL. | 5,485 | 958 | 5,254 |
| 17 | Norfolk, VA (city) | 5,037 | 53 | 267 |
| 18 | Union, NJ | 4,886 | 103 | 504 |
| 19 | Falls Church, VA (city) | 4,830 | 2 | 10 |
| 20 | Nassau, NY, | 4,610 | 287 | 1,322 |
| 21 | Denver CO..... | 4,452 | 111 | 492 |
| 22 | Milwaukee Wl | 3,997 | 241 | 965 |
| 23 | Charlottesville, VA.. | 3,827 | 10 | 40 |
| 24 | Wayne, Ml.. | 3,801 | 615 | 2,338 |
| 25 | Richmond, VA (city) | 3,650 | 60 | 219 |

SOURCE County and City Data Book,1983 Department of Commerce, Bureau of the Census Population Data based on 1980 census

nations would be required to produce 3 psi overpressure over a total area of 2,000 square miles, and 80 would be required to produce 5 psi over the same area. The most populous 2,000 square miles contains about 17 million people.

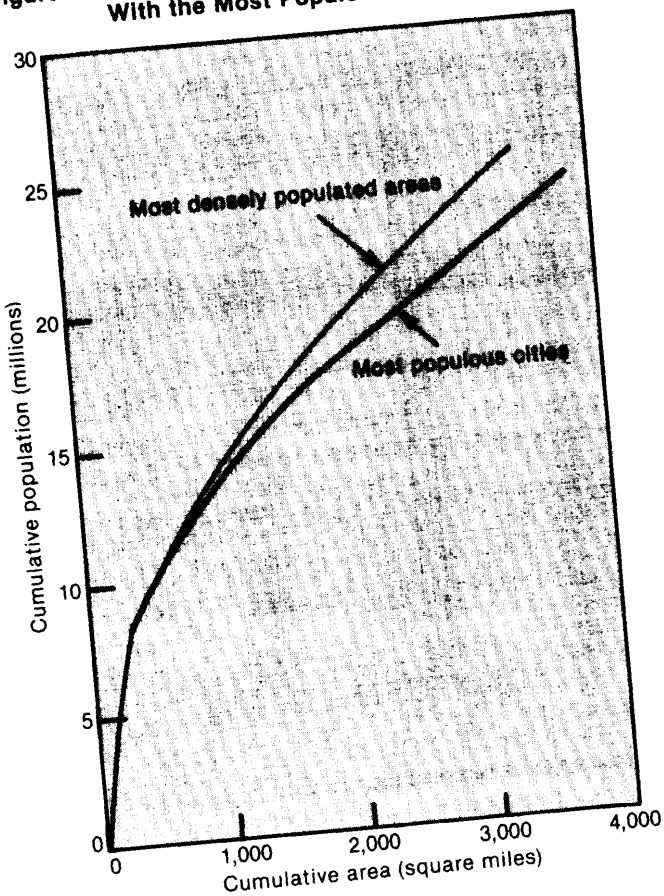
We can now calculate the expected number of casualties from an attack on our population, as a function of the effectiveness of our BMD as measured by the probability that an RV is killed by it, $P_k$. In the worst case, the Soviets use all their weapons against a number of aimpoints equal to the number of RVs they expect to penetrate the defense, 9,000( 1-Pk), and their weapons detonate successfully at all of them. They pick the most populous aimpoints. This provides an upper bound on the number of prompt casualties, In the other case, they allocate 100 of their weapons against each of the 90 most lucrative aimpoints. In this case the probability that any aimpoint is destroyed is given by the expression $1\text{-}P_k^{100}$. The number of prompt casualties is this multiplied by the total population at those aimpoints, which is about 25 million for 3 psi coverage and about 20 million for 5 psi coverage.

Figures D-3 and D-4 show the results for the four cases. They show the number of casualties as a function of the effectiveness of the U.S. BMD system. Figure D-3 shows what the number of casualties would be if one believes that 3 psi is sufficient to kill almost everyone, and figure D-4 shows what the results would be if one believes that 5 psi is necessary.

## Basic Observations

If the Soviets were intent on killing Americans, it would require an extremely capable defense to keep casualties "low." A defense that permitted 1 percent of the Soviet weapons through might result in casualties well in excess of 10 million. It would appear that keeping casualties below 1 million would require a defense that could stop in excess of 99.9 percent of the Soviet attack. While we would need defenses with these capabilities to be confident that we could keep casualties low, lesser (but still quite capable) defenses might result in casualties much lower than what is indicated in this worst case analysis. Soviet weapons might not be so heavily concentrated on a few cities, and populations might evacuate or take other protective measures, Finally, not everyone agrees that assured survival requires guaranteeing very low expected casualties. By some definitions, the nation would survive even if millions of Americans did not.

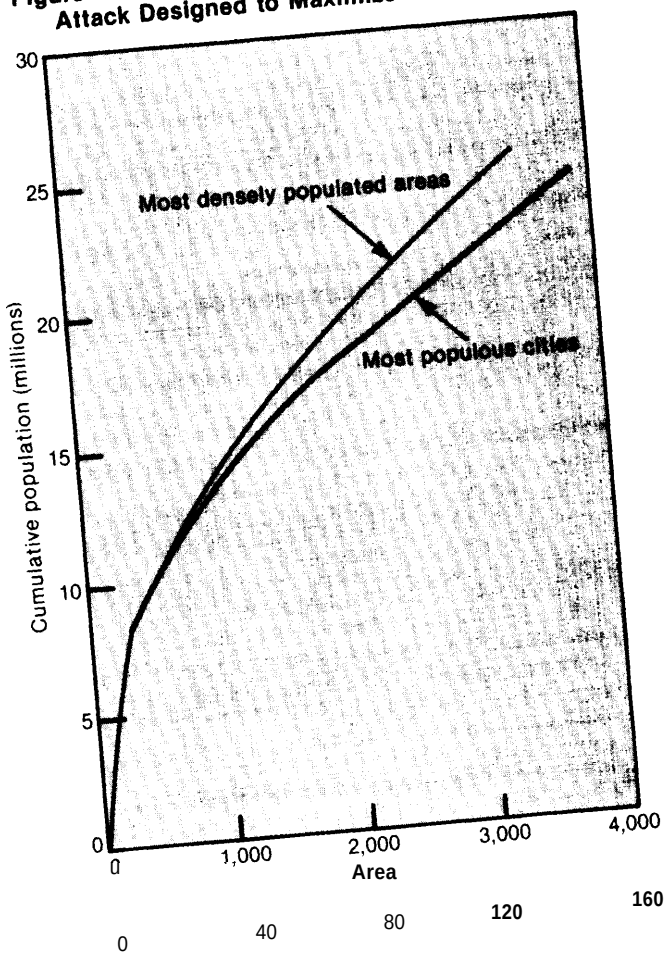
Figure D-1.—Cumulative U.S. Population Beginning With the Most Populous Areas




**Note: Curves have been smoothed"**

***SOURCE*** Office of Technology Assessment'

Figure D-2.—U.S. Population at Risk to a Soviet Attack Designed to Maximize Casualties

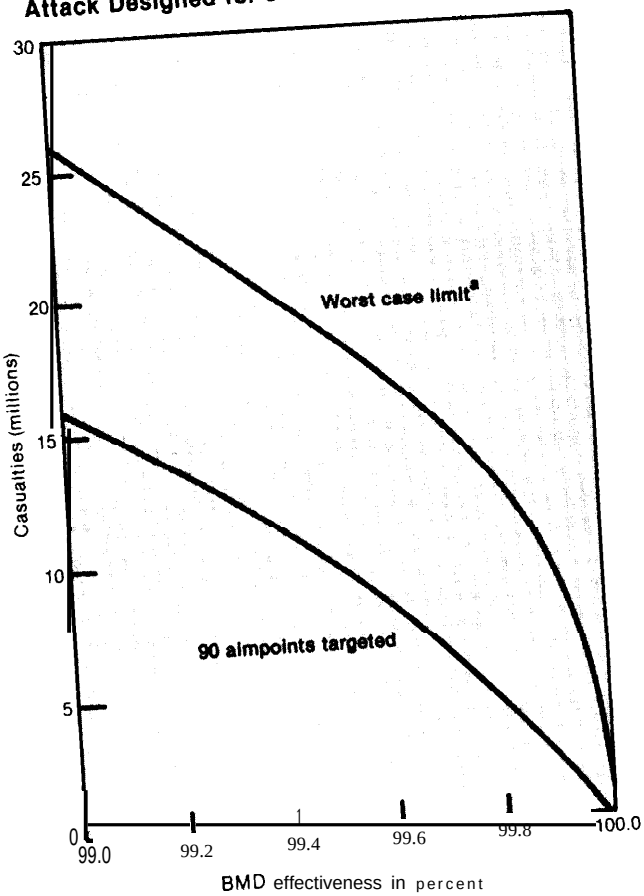



**Number of** weapons to produc[e] at least 5 psi over entire area

**Numbe[r] of weapons to produc[e] at least 3 psi over entire area**

**SOURCE Office** of Technology Assessment

**Figure D-3.—Potential Casualties From a 9,000 RV Soviet Attack Designed to Maximize Casualties: Attack Designed for 3 PSI Over Target Areas**

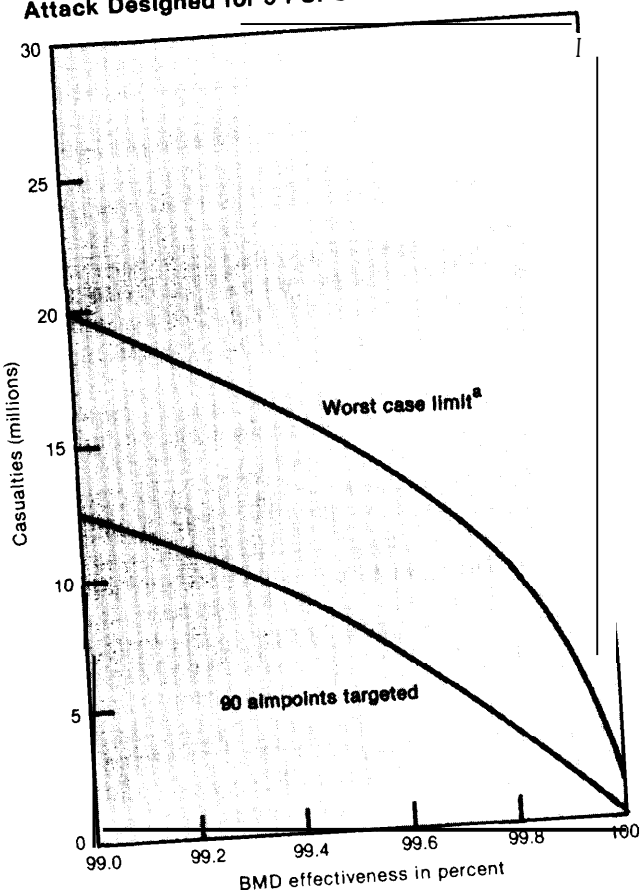



defense IS and target accordingly

[a]Soviets know exactly how capable U S
They hit every city they target

SOURCE" Office of Technology Assessment

**Figure D-4.—Potential Casualties From a 9,000 RV Soviet Attack Designed to Maximize Casualties: Attack Designed for 5 PSI Over Target Areas**




**Soviets** know exactly how capable U S. defense is and target accordingly
They hit every city they target

SOURCE' Office of Technology Assessment