In this third article of its series, Air Targets solves for the most elementary unknown in its threat-vulnerability equations.

DEVELOPMENTS IN AIR TARGETING: THE DAMAGE ASSESSMENT MODEL

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The primary mission of air targeting is the identification of opportunities for air action. The identification of these opportunities requires an exhaustive study of many aspects of the structure of potential enemy nations. Each of the important resources of these nations must be evaluated, measured, and, if possible, associated with specific geographic locations. The contributions of these resources to the strengths of the enemy must be evaluated. The motivations and national objectives of the enemy must, in turn, be studied to determine the probable threats posed by his available strengths. Having defined the threats posed, it is then possible to return to the resources which were critical to the strengths underlying these threats and assess their vulnerability to air attack. Through the assessment of the vulnerability of many combinations of resources, opportunities for optimum air action can be identified. This analytic process, proceeding from the enemy's resources and strengths to the threats he poses and from his vulnerabilities to the opportunities they provide for air action, is what air targeting calls "comprehensive analysis."

The analytic model described in a previous issue, the Military Resources Model,[1] can be thought of primarily as an aid in the analysis of resources to determine strengths. The Air Battle Model, also described previously,[2] and the Damage Assessment Model, considered here, are primarily concerned with the measurement of threats and the assessment of vulnerability. Since an enemy threat can best be measured in terms of our vulnerability to it, both of these elements reduce essentially to measurements of vulnerability.

[1] *Studies in Intelligence*, Vol. 2 No. 1, Winter 1958, pp. 51–64.

[2] *Ibid.*, Vol. 2 No. 2, Spring 1958, pp. 13–32.

Vulnerability in this sense covers a wide range. In particular, it includes by inversion the time-phased capabilities of the two (or more) antagonists *in relation to each other*. The purpose of the Air Battle Model is to keep under calculation the interacting and fluctuating capabilities related to the progress of an air war. It disregards other capabilities, military, social, and economic, which do not affect the progress of the air battle. Determining the vulnerability of these remaining capabilities and strengths requires additional analysis. Basic to both the Air Battle Model and this analysis of other capabilities is an ability to predict the effects of weapons and weapon systems used by the opposing forces. The Damage Assessment Model has been developed to meet this requirement.

The Theory of Damage Assessment

"Damage assessment" as used here is limited to mean prediction of the probable effects of hypothetical applications of atomic weapons or weapon systems to specific targets or target systems. The Model is simply a body of analytic procedures which have been standardized to the point where they can either be manipulated even by people who don't understand them or fed into high-speed computers. The Damage Assessment Model is a growing body of highly flexible analytic procedures, capable of utilizing rapidly changing data with regard to atomic explosions in predicting the probable physical, functional, or operational effects of atomic weapons on targets or target systems.

In a relatively simple example, the Damage Assessment Model predicts the effects of attack on a specific airfield with an atomic weapon of given yield which is burst at a particular height. This prediction is usually in straightforward terms of physical effect, such as probable fraction of aircraft rendered inoperative, probable fraction of hangars collapsed, or residual contamination in the maintenance area after four hours. Interpretations of these physical effects may be computed, however. In this simple case, the calculation of contamination intensities, blast damage, and thermal and initial gamma radiation fluxes may be combined with intelligence or assumptions about personnel distributions and shielding to produce injury and fatality estimates. More complex cases involve functional or operational interpretations of physical effects. These interpretations are important, but the basic building block for all damage assessment is the capability to predict the probable *physical effects* on targets of a projected attack.

George F. Kennan has written in a recent article in *Harpers Magazine*, "I do not believe there is any human mind or group of human minds or any calculating machine anywhere in the world which can predict with accuracy what would happen if these weapons should begin to be used. . . ." His proposition as stated is undoubtedly right. Prediction of the total effect of atomic attacks is an overwhelmingly difficult problem. Probably the most difficult part of it is the assessment of human reactions, like for example that of the doctor at Hiroshima who painted severe burns with iodine. Most of the available evidence indicates that people cannot be trained to accept catastrophe.

Even with the more limited problem of predicting the specific physical effects of atomic attack, it is not evident what physical effects should be selected for prediction. Any damage prediction presumes a prediction of the occurrence or non-occurrence of some selected type of damage. The questions asked must be of the type "Did the building collapse?" not of the type "What happened?" Determining what questions to ask is itself an abstract question requiring careful analysis.

These two aspects of the total problem, the assessment of human reactions and the selection of the physical or other effects to be predicted, are both under continuing investigation. The purpose of this article is to describe only the first step in the solution, the development of a capability to predict specific selected physical effects. This capability, which now exists in the Damage Assessment Model, has considerable importance in its own right, without regard to the solution of the larger problems. There are many problems requiring only comparative accuracy which are susceptible of solution with such a model. Questions about the advisability of using alternative weapon systems or strategies can be attacked through the computation of even arbitrarily selected physical effects to show the relative advantages of each with respect to these effects. And while prediction of the total effect of atomic attack is not possible, it is certainly possible to develop techniques for indicating the order of magnitude of some of the effects.

The Operation of the Model

The Damage Assessment Model can be divided conceptually into two parts, the first for assessing the direct effects of atomic weapons—blast, thermal radiation, and initial gamma radiation—and the second for estimating residual contamination or fallout. Of the direct effects, attention has been focused primarily on blast, and the procedures for calculating blast damage are here described in greatest detail.

The conceptual framework for the assessment of blast effects was developed from analysis of the damage at Hiroshima and Nagasaki. Analysis of these data indicated that any system for predicting blast damage must take into account the rather awkward fact that many structures near the bomb-burst survived while structures of similar construction farther away were damaged. If a weapon were burst over an extensive housing development of uniform construction, the result might be pictured as in Figure 1. In this figure each black square indicates a building that collapsed, and each white square one that did not. It will be noted that there is no sharp line between those collapsed and those left standing.

Figure 2 shows a plot of the data on one type of structure at Hiroshima and Nagasaki. The curve shown is a statistical best fit to the data; it associates with each distance a probability of occurrence for a particular type of damage. Statistical analysis of a series of such fits to data on Hiroshima and Nagasaki indicated that the probability functions for all of the various categories of structures in these two cities were remarkably similar.

If a series of these similar probability curves is drawn successively along the distance axis of Figure 2, each such curve, identified by its mean distance, can be thought of as representing a vulnerability class. These classes were assigned vulnerability numbers, VN's, and through weapons effects tests the distance range of each was translated into an equivalent range of overpressures. The VN classes thus define the probability associated with any distance or overpressure. The obvious question with regard to this last sentence is, probability of what? The answer is probability of any kind of damage, since the scale itself is a general one unrelated to any specific damage effects.

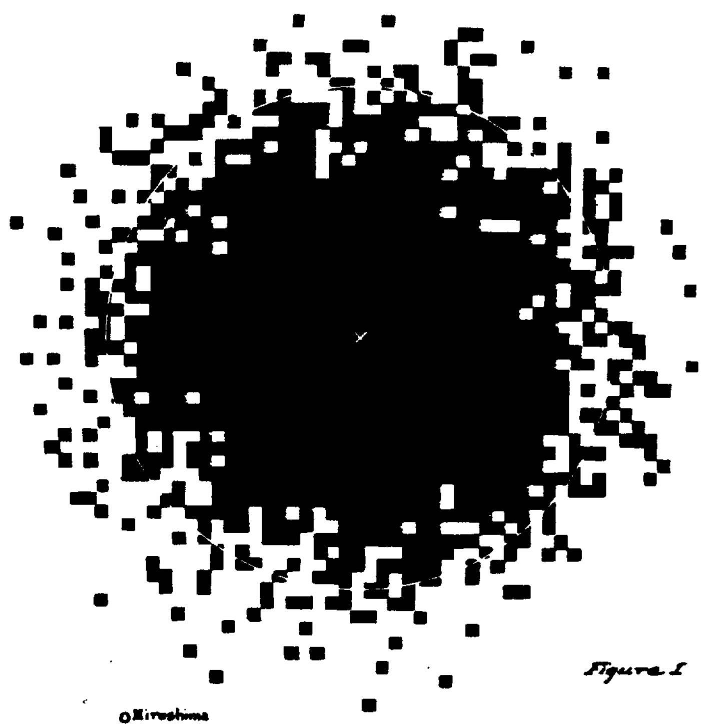

Figure I

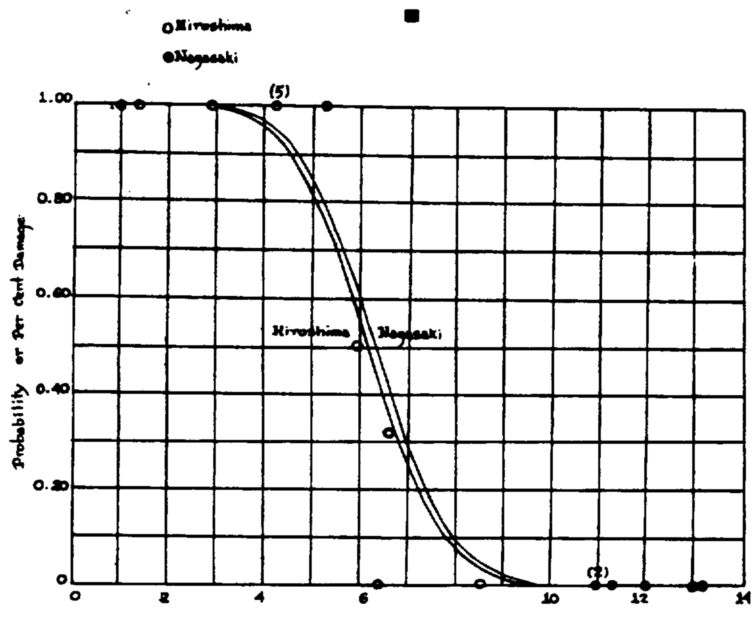

Figure 2

Given a particular kind of damage, however, the overpressure associated with 50 percent probability of the occurrence of that damage can be estimated, and the probability of that damage at other overpressures can be estimated, by selecting the appropriate VN. In addition, the extensive data available from atomic tests can be used to predict the overpressure at particular distances over a wide range of weapon yields and heights of burst. Thus the assignment of a VN class to a target to define the probability of some particular type of damage allows the prediction of this probability for any weapon yield or height of burst. The selection of VN's for a variety of kinds of damage on many different types of structures and targets has been accomplished on the basis of data from the Japanese experience, atomic test data, and theoretical calculations.

The handling of thermal and gamma radiation is done with probability functions similar to those used in blast analysis. The system thus allows the prediction of any type of damage. Pre-analysis is required to determine, on the basis of the vulnerability of the target and the type of damage to be predicted, which vulnerability classification is appropriate. The model then provides for estimating the probability of this type of damage.

The technique used in estimating residual contamination is basically different from that used in the analysis of direct effects. Whereas the analysis of direct effects is based on a probability curve and results in a statement about the probability of some type of damage to a particular target, the contamination assessment model produces definite answers about absolute intensities or doses. This difference does not arise from any predictability of fallout as opposed to unpredictability of direct effects. On the contrary, it results from the difficulty of constructing a probability model of fallout; analytic effort has not succeeded in developing a probability model of fallout patterns, which depend upon unpredictable weather conditions among other factors.

Contamination analysis, however, is usually applied only to large target systems, where accuracy with respect to individual targets is less important than average estimates for the whole system. The Model allows the computation of estimated contamination levels based on a stylized contamination pattern, given the assumed weather conditions at the time of the burst, the location of the burst, and the type and yield of the weapon. The Model provides for estimating intensities or doses at any time after the initiation of hostilities.

It may be noted that the definition of this Model does not require that it be available on a computer. The description of its two parts, one for direct effects and one for contamination assessment, is applicable to either a hand or a computerized model. The Model is available in either form. Numerous technical manuals have been prepared describing the use of these procedures in hand analysis. Programs have also been developed for several computers, mechanizing the preparation of damage assessments by the Model. The requirement for a computer program is evident from the magnitude of present targeting problems. In one recent study, roughly 1,000 high-yield weapons were gamed against a system of 40,000 targets and target areas. Thirteen hours of computer time were required to produce twelve damage answers on each target or target area, a total of nearly 500,000 predictions. A problem of this size is well beyond the capabilities of hand analysis.

The Damage Assessment Model herein described is only one of several such models which have been developed to serve this purpose. The development of a single, standardized damage assessment model is now being actively pursued in the Department of Defense. It is expected, however, that such a standardized model will adhere quite closely to the concepts illustrated in this article.