PSR Note 567

FIRE DAMAGE AND STRATEGIC TARGETING

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TABLE OF CONTENTS

PREFACE

This report is one of a 16 volume set comprising the Pacific-Sierra Research Corporation (PSR) final report on Defense Nuclear Agency (DNA) contract DNA 001-82-C-0046. The work done under this contract spans a wide range of nuclear weapon effect research covering airblast, cratering and ground motion, low-dose radiation, underground test design and development, fire research, and electromagnetic pulse research. The contract technical monitor was Cyrus P. Knowles.

In a recent effort for DNA, H. L. Brode and R. D. Small of PSR cooperated with R. Port and E. Carson of R & D Associates (RDA) in a study to examine the potential role of fire in urban/industrial area targeting. The intent of this exercise was to explore the possible consequences of including fire damage in targeting and damage assessments and to illuminate those aspects of fire prediction that are both most uncertain and most important. This study would hopefully aid in guiding fire research.

The results were briefed to DNA, and included in reports to the JSTPS Scientific Advisory Group. This report summarizes the fire phenomenology contributions made by PSR. The targeting exercises (by RDA), using these PSR inputs, and our joint results and conclusions will be reported separately. The recent death of R. Port will make the completion and summarization of the targeting effects exceedingly difficult.

This task was supervised by Michael J. Frankel.

SUMMARY

The blast wave and the thermal, electromagnetic, and nuclear radiations from a nuclear explosion can all contribute to target damage. Current strategic targeting considers structural damage from the blast wave only. Although fire damage can be more intensive and occur at greater ranges, it is treated as a bonus effect and thus not included in targeting or damage assessments. Since the variables controlling fire damage have been considered too uncertain to allow reliable fire damage predictions, there has been little impetus to modify targeting strategies to account for this added effect.

This report relates the probability of fire damage to blast-induced ignitions and those due to thermal radiation. Modifying influences such as weather conditions, target structure, and countermeasures are included. Since fires continue to develop long after the explosion, additional effects such as fire spread and fire-wind damage are also considered. The methods may be extended to calculate probable damage ranges for a specific target, and may be made compatible with current targeting algorithms (the DIA vulnerability number methodology).

"Reasonable" parameter values lead to fire damage ranges that extend into low overpressure regions. Less conservative--though still reasonable--values result in damage ranges exceeding comparable blast damage ranges. These results could help justify enlarging the scope of current targeting strategies to include fire effects. This study identifies those aspects of urban fires from nuclear attack that are most influential in determining the extent of fire damage and are still uncertain. These factors are proper candidates for further Defense Nuclear Agency research.

SECTION 1

INTRODUCTION

A nuclear weapon explosion will cause extensive blast damage and ignite many fires. Though damage radii characterizing probable blast destruction have been defined, comparable methods to estimate fire damage radii have not been developed. In view of the widespread and uniform fire damage observed at Hiroshima and Nagasaki, consideration of blast damage alone may underestimate the potential destruction from a nuclear weapon explosion.

There are several reasons why fires have been considered a bonus effect rather than a principal damage agent. Historically, fire has been viewed as largely unpredictable and too subject to the vagaries of weather and the errors in weapon delivery to be a reliable damage mechanism. Despite the uncertainties, World War II planners pursued a program of fire bombing raids. In many cases, damage was less than expected but still greater than could be achieved with general-purpose (explosive) bombs. In others, large conflagrations developed, and damage far exceeded predictions. As the war progressed, attacks on urban/industrial concentrations relied on fire bombing as the most effective damage mechanism.

A nuclear weapon is the modern analog to the raids by a thousand aircraft carrying mixes of thermite and high-explosive bombs. The concentration of the fire-causative mechanisms in a single nuclear warhead ensures a very large number of ignitions and the rapid development of a large area fire. Weather and other conventional modifying influences on small fires may be less important or reasonably predictable effects for large fires with multitudinous ignition sources. As a consequence, it may be reasonable to reconsider the inclusion of fire effects in target damage assessments.

The analysis in this report employs broad assumptions about large urban fires in order to provide inputs to a targeting study. A general relation is hypothesized to define fire damage as a function of range

for an urban area. The sensitivity of each parameter is evaluated by varying its values and noting its influence on the fire distribution. Some additional parameters not explicitly explored in the model are identified and discussed.

The principal parameters considered here are weapon yield, height of burst, threshold ignition levels, visibility length, atmospheric transmissivity, enhancement and attenuation of the thermal radiation due to clouds and snow cover, blast-induced ignitions as a function of building type and contents, fire spread, fire winds, and countermeasures. Following a systematic variation of each parameter, combinations of effects as well as combined expected deviations are considered. The results identify the sensitivity of each variable and its relative importance to the damage-range relation. Simultaneous variation of the group of parameters provides some insight into the likely overall uncertainty in fire damage predictions.

An alternative fire damage methodology for strategic targeting applications might supplement the current vulnerability number (VN) system with designations representing potential fire damage to each specified target. Such an expanded VN system has not yet been developed, but the elements for its creation are included here.

SECTION 10

CONCLUSIONS

The fire vulnerability analysis developed in this report has been used to estimate damage ranges based on the target vulnerabilities to fire starts, the immediate weapon effect-target interaction, and the later time fire development. Modifications due to weather conditions, civil defense measures, and uncertainties or variations in atmospheric transmission and target vulnerabilities were considered. Mean and standard deviation fire-damage-range curves were presented for two weapon yields. The results provide a measure of expected fire damage ranges. In general, fire damage radii exceed those for moderate blast damage.

Despite the uncertainties, fire damage can be predicted with useful consistency; such predictions could become as reliable as corresponding blast damage predictions. The inclusion of fire in the damage prediction methodology would improve and extend current damage assessments. In addition to greater damage radii, fire may cause more complete and permanent damage. A structure only moderately damaged by blast may be gutted and rendered useless by fire. Similarly, building contents may survive the blast but be destroyed by the fires.

Some improvements and new directions might be pursued to further develop such a fire-damage-prediction method. Variables not explicitly considered in this study include blast-flame interactions, target shielding by adjacent buildings or topographical features, variable city construction and vulnerabilities, fire breaks, and multiple-burst effects such as target shielding by dust and smoke. Many of these effects, though potentially important, may provide only modest changes in the overall damage prediction. A fire damage model applicable for multiple-weapon attacks is needed.

A fire damage prediction must be based to some extent on the target structure vulnerability. A simplified method might involve a classification system that relates the target vulnerability to burst characteristics such as the total thermal flux or the blast pressure or impulse.

One possibility might be to alter the VN target designation to include the probability of fire damage. Such a revision would be operationally convenient. Alternatively, an added vulnerability designation (FVN) specifically for fire damage probability could be generated for each target. This evaluation would weigh such additional factors as the ignition susceptibility of the structure and contents, the likelihood of blast-induced fire starts, and the proximity of other equally or more susceptible structures from which the fire might spread. Such added considerations would require more computation in arriving at weapon application plans, but potentially may reduce the number and yield of weapons required to achieve specified damage levels or improve estimates of their effectiveness.

The VN system was constructed some three decades ago when both weapons and targets were fewer, smaller, and simpler. The system is well established, but increasingly complex for modern weapon allocation alternatives. Long computer runs are often involved. Although most targets and all cities are vulnerable to fire damage, these vulnerabilities are not now included in the VN system or in damage considerations. The effects of a nuclear attack are thus understated.

The vagarious nature of and lack of specifics in declared national objectives in the use of strategic forces against urban areas, C-3 targets, leadership targets, military targets, or industrial targets make comprehensive damage evaluation difficult. The explicit exclusion of population, living space, and commercial and cultural edifices in targeting is at best confusing, since such nontargets are not avoided, and so are implicitly included, even though never counted in assessments of value destroyed. Both blast and fire will damage targets (industrial sites) and nontargets (apartments); but fire will generally go farther and cause more complete damage to both.

A new damage methodology including fire effects need not wait for changes in national objectives. If "moderate damage" to "steel frame" buildings is the appropriate guide for destroying a city of a million or more inhabitants, then fire can only complete the job more effectively.

Recent concerns for the adequacy of current criteria and for the consequent choices of overpressure levels and burst heights could be relieved or removed by the inclusion of fire damage.

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