VULNERABILITY OF QUICK-REACTING SHELTERED MISSILES AND AIRCRAFT DURING LAUNCH

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Summary

The residual effects of a multi-megaton ground burst which is used to
attack a sheltered missile or airplane creates an environment which makes
launching attempts hazardous at early times after the burst. In order to
illustrate, the quantitative aspects of the problem, estimates of the
hazards and their variation with time are shown for a particular set of
assumed circumstances.
I. Introduction

Some aspects of the vulnerability of sheltered missiles and aircraft has been considered in two previous papers [Ref. 1 and 2]. The general conclusion drawn is that the system can be hardened to almost any desired degree and assure a high probability of survival thereby. However, when quick-reacting shelters, which can launch their birds within minutes after an attack, are visualized, we find that the system is somewhat vulnerable during this launching phase. The extent of this vulnerability must be taken into consideration in studies of the military operations of these systems.

In order to gain an insight into the parameters and numbers involved we shall carry through "typical calculations" of the vulnerability as a function of time. Quotation marks surround the phase, typical calculations, because (a) there is no such thing as typical and (b) the calculation is hardly more than a numerical exercise based upon heuristic estimates or, better yet, guesstimates, of the important parameters which are the heart and soul of the problem. These parameters (residual effects following an enemy surface detonation) are listed here for the sake of completeness. References 1, 2, and 3 should be consulted for details.

1. Wind velocities as a function of time and space.
2. Dust density as a function of time and space.
3. Sand density in the air as a function of time and space.
4. Stone density in the air as a function of time and space for each rock size.
5. Debris density (as a function of surface coordinates) which arises from the interaction of the blast wave with surface structures and vegetation and from crater throwout.

6. Gamma radiation field as a function of time and space.

7. Wind velocities as a consequence of the firestorm which will be determined by the special distribution of combustible material.

The launching of manned bombers will be hampered by all of the above items. The launching of remote-control missiles will be hampered by items 1, 3, 4, 7. We will, in our typical examples, consider: (a) A bomber equipped with rockets for zero-length-launch, taking off directly from the shelter or apron outside the shelter. (b) A bomber which taxis to a nearby runway and requires several thousand feet of ground roll for take off. (c) A missile launched from a concrete silo (e.g., the Titan configuration).

II. The Zero-Length-Launch (ZEL) Manned Bomber.

We consider here as a specific example the B-58 shelter as designed recently by Paul Weidlinger [Ref. 4], and assume that the bomber has survived at the 200 psi overpressure level. This particular shelter design eliminates the threat of dust and debris from among the seven items listed above. For each of the other effects (wind, sand, stones, radiation, firestorm) an estimate of the vulnerability of the launch effort as a function of time is shown in Figure 1. In this figure the probability of an abort as a result of each of these effects is plotted as a function of time-after-burst of a multi-MT weapon. The total probability of abort is found by compounding these effects and this result is also given.
The results of figure 1 contain rather large uncertainties, some of which arise from our ignorance regarding the early-time close-in effects of nuclear weapons and some of which depend sensitively upon parameters such as topography, type of soil, potential debris sources, prevailing local weather, etc. None of the individual curves shown in the figure represents an extreme estimate but some guess between extremes. We will consider each of them briefly.

(i) **Wind**: Reference 1 estimates that wind velocities dangerous for aircraft may exist for up to 20 minutes as a result of the pumping action of the rising fireball. Because (a) 20 minutes seems to be an extreme figure, (b) the strongest ground wind gusts may be localized near the edge of the stem, and (c) the wind will not necessarily be side-on, the actual curve used in Figure 1 assumes 40 per cent vulnerability at six minutes after burst with a rapid decrease thereafter. An actual situation could be considerably more threatening in my estimation -- especially if an ambient wind of 10-15 mph existed.

(ii) **Sand**: The sand threat (discussed in Ref. 1) has two principal components, the ingestion effect on the engines and the visibility effect on the windshield. This threat decreases monotonically with time as the sand settles out of the air. The plot in Figure 1 is an intuitive guess based upon a rather reasonable estimate that for a surface burst one MT of soil is carried aloft by each MT of yield (see Ref. 5). It is clear that the nature of the soil is an important parameter here but quantitative relationships have not yet been developed. Actually, the threat at any single location would probably be 100 per cent vulnerability up to some
time, $t^*$, after which the vulnerability would be zero. In other words, a go, no-go situation. The use of a smooth estimate is justified partly by uncertainty about $t^*$ and partly because $t^*$, if known, would be different at different sites.

(iii) **Stones:** The possibility that, following a surface burst, a rock shower lasting several minutes may occur was shown by Brode [Ref. 6] and is discussed in Reference 1. Brode's calculation shows that the necessary forces exist in the rising stem to sustain such a shower. However, because no known mechanism has yet been specified which can inject stones into the stem, the threat is considered small and monotonically decreasing with time. Figure 1 shows the simple choice that has been assumed.

(iv) **Radiation:** The dose rate which may be found to exist at early times in the 200 psi region is discussed in Ref. 2. There radiation of 100,000 r. per hr. at times like 8 minutes after burst was suggested as an upper limit and the variation with time was computed for a given set of assumptions. For a ZEL B-58 bomber efficiently launched from the Weidlinger shelter (which has special radiation protection included in the design), a computation has been made which gives the result that the crew receives a total dose of .007N, where N is the dose rate in r/hr at launch time. This would give a dose up to 700 roentgens, an amount believed to be certain death to all the crew. The actual choice in Figure 1 is considerably less than this (consistent with the policy of not taking extremes) and shows a threat estimated on a radiation field of about 1/4 of the assumed maximum. Therefore at 8 minutes each of the crew would
get about 175 r which is assumed to give about 33 per cent abort probability because of radiation sickness before arrival at the programmed destination. (Radiation sickness usually begins roughly three hours after exposure. When the crew and bomber are considered expendable, the radiation threat is considerably reduced for targets less than three hours away.)

Some of the uncertainties in calculating radiation vulnerability (in addition to the large uncertainty in the dose rate near the ground) are

(a) time interval required for launching in the post-attack environment,
(b) variation of dose rate with height above ground in non-uniform distribution of activity, (c) direction of take off with respect to ground zero, and (d) ability of irradiated crew to carry out mission.

(v) Firestorm: While all of the above threats diminish steadily with time, the firestorm [Ref. 2] increases from zero time to a maximum which depends upon the distribution of combustible material in the area within 20 miles of ground zero. Cities and forests probably will take 1-3 hours to build up to a maximum, dry wheat or corn fields probably just a few minutes. The South Dakota Badlands have nothing to burn. Our choice in Figure 1 is therefore quite arbitrary both as to the duration and intensity of the threat. For any particular shelter site, however, this effect could be reasonably estimated after a study of the surrounding environment.

III. The "Ground-Roll" Bomber.

If now the B-58 visualized in Section II does not have ZEL equipment, our vulnerability curves must be modified (see figure 2), to take into consideration that the aircraft will require a long ground roll in order to take off. The following considerations are important:
(i) The radiation threat is substantially increased since (a) the bomber must taxi out of its protective haven to an above-surface position for take off. It follows that (a) the mean dose rate is much higher, and (b) the total exposure (taxi and ground roll time) is greater. The airplane may even pick up some radioactivity on its landing gear and convey it into the belly of the airplane where it will irradiate the crew during the flight. Because of these phenomena the radiation vulnerability shown in Figure 2 is substantially greater than that of Figure 1.

(ii) Dust. The problem of dust will exist whenever the pilot is required to see in order to taxi out of the shelter, to the taxiway, along the taxiway to the airstrip, and along the airstrip for take off. But in the post-burst environment, visibility will be practically zero at all early times. However, because it should be possible to engineer a system to counteract the dust effect, the dust vulnerability chosen in Figure 2 has been made small, anticipating a reasonably effective solution as part of the system design.

(iii) Debris on the runway. This effect, which is examined closely in Ref. 3, can in some respects be the most aggravating of all. Runway clearing equipment is simply not practical for quick-reacting shelters where the first 30 minutes is critical. While Ref. 3 shows that the debris problem can be nearly eliminated by appropriate site planning and structure design, there is always a substantial chance that compromises will be made which increase the threat. Besides there are present certain random factors such as normal vehicle traffic near the base (or an occasional boulder arriving from the crater) which can end up on the runway. We conclude that even though the problem is well anticipated, an assumed probability
of 10 per cent attrition from debris (used in Figure 2) is nominal.

IV. The Missile in the Silo

Of the seven threats mentioned in Section I, four apply to a missile launched vertically from a hard silo. These are wind, sand, stones, and firestorm. Reference 1 discusses the first three of these and Reference 2 discusses the firestorm effect. For each of these the threat is expected to be less for a missile than for an airplane. In Figure 3 an estimate of these as a function of time is given together with the total vulnerability. It will be noticed that between the winds raised by the fireball and those of the subsequent firestorm, there is a period of relative safety. In the chosen example the minimum in the vulnerability-time curve occurs 15 minutes after the bomb has exploded.

V. Eliminating the Radiation Threat

It can be seen from Figures 1 and 2 that residual radiation is the principal threat to effective launch under the hypotheses of our chosen examples. To emphasize that there are the underlying hypotheses and in order to prevent the curves of Figure 1 and 2 from becoming psychologically entrenched as the final answer, we offer Figure 4 which shows the reduced total vulnerability of a bomber when the radiation threat has been eliminated. This figure is needed for at least two reasons:

(a) The radiation field, for distances greater than that at the 200 psi range, will diminish rapidly according to the model by which the gamma-field (Ref. 2) was estimated. This decrease with distance is so rapid that the residual radiation threat is expected to vanish somewhere between the 50 and 100 psi ranges. Thus, for those shelters which experience
less than the maximum overpressure, we need to contend with a reduced radiation threat during the subsequent launch of the bomber.

(b) The possibility of using shielding inside the airplane has not been considered in the calculations so far. This is distinctly feasible and would of course reduce, if not completely remove, the radiation hazard.

VI. Multiple Bursts

If the sheltered system is subjected to several bursts, the subsequent vulnerability during the launch phase will have different time graphs from those shown in Figures 1-4. The following qualitative comments can be made about the seven individual threats we have been discussing.

a) Wind, dust, sand, stones: For these the vulnerability will be essentially the same as that from a single burst.

b) Debris: This hazard will increase monotonically with the number of bursts. The threat may even increase faster than linear. That is, two bursts may increase the threat from say 10 per cent to 30 per cent.

The reason for this is that part of the site design which keeps the debris away from crucial areas can be effective for a single burst but not for the rescattering which attends subsequent bursts.

c) Residual Radiation: This effect will essentially be additive. The existing fallout or throwout may be redistributed somewhat by a subsequent burst and therefore increase or decrease the hazard. Statistically we simply ignore this redistribution.

d) Firestorm: This effect after a subsequent burst may be either greater than or less than that experienced after the initial burst. The
reason for this is that the firestorm reaches a maximum anywhere from a few minutes to a few hours depending upon the nature and the distribution of combustible material near the base. The time of emergence after a multiple burst attack may coincide with a waxing or waning firestorm. As indicated earlier the firestorm effect can be estimated once the nature and distribution of combustible material is known. This is true for the multiple burst situation as well.

Looking at the above points shows that in summary the attack with more than one bomb increases the launch hazard for an airplane more than for a missile. The principal worry is that of debris. It should be emphasized that the debris threat is one over which we can exercise a great deal of control [Ref. 3] and the threat can be eliminated by sufficiently careful design of the overall base and surrounding site.

VII. Remarks on the Quantitative Aspects

The criticism that the total vulnerability calculated herein is in great doubt since each of the elements comprising it has large uncertainty must, of course, be accepted in advance. However, such criticism does not imply that a better alternative is to ignore the threats. We can respond in two ways. First, Figures 1-4 can be drawn with an air brush instead of the solid lines. Secondly, and more usefully, we can suggest that the problem be attacked by a substantial research effort. Some of the problems may yield to theoretical efforts and the gleaning of previous test data. A really satisfactory resolution will come only when an experimental program is devised to study this problem in future weapons testing (if any).

Finally, it should be pointed out here that we may have (or should I
say, probably have) overlooked some aspect(s) of the hostile environment following a surface burst. As of about one year ago hazards such as the dust, wind, and firestorm were not being considered. More reflection (if not actual experience) may acquaint us with others. While no such allowance has been made in Figures 1-4, systems analysts may want to throw in a contingency factor for the unknown threat.
References


Fig. 1—Probability of a sheltered (200-500 psi) ZEL BOMBER aborting during launch as a function of time after enemy attack
Fig. 2—Probability of a sheltered (200-500 psi) bomber aborting during launch as a function of time after enemy attack. Ground-roll required.
Fig. 3—Probability of a sheltered (200-500 psi) missile aborting during launch as a function of time after enemy attack
Fig. 4 — Total probability of a sheltered bomber aborting during launch when residual radiation is negligible