and other components of the contact fuze systems are assumed to be unity for the purposes of the calculations.

The procedures of Reference 2 require that the geometries of the contact fuze sensitive regions (on the weapon case) are such that their forward projections are (approximately) annular. It is assumed that the two design proposals (Systems 1 and 2) for the XW-5/F-101 provide sensitive-region geometries having annular forward projections, and no distinction between the two systems is made in performing the probability calculations. It is, therefore, impossible to compare Systems 1 and 2 on the basis of probability arguments unless it can be established that one or more of the following factors exists to force a choice between the two design proposals:

1. The geometry of the sensitive region of one system more nearly satisfies the assumption of an annular forward projection.

2. The arrangement of the MC-300 impact crystals and associated networks of one system is more reliable.

3. Some factor, other than the specific probabilities of this memorandum, exists to force a choice between System 1 and System 2.

The various formulas and measures used in the calculations are not reproduced in this memorandum because of the complicated nature of the calculation procedures; for those who are interested, the entire set of computations is available in the files of Section 5131-1. The geometry of, and measures for, the XW-5/F-101 weapon were assumed to be in accordance with the data appearing in SC-3245 (TR)[3]. It was assumed that the fuel tank in the forward section did not constitute a vital component and its presence or absence was not essential to the calculations.

Flight characteristics of the weapon were taken from the data of Reference 3. A five-degree angle of attack was assumed to be maximum for the weapon. The calculated probabilities of damaging penetration are maximized probabilities for a composite target from a strategic target complex. Calculations were performed for impact angles of 15, 30, 45, 60, 75, 90, 105, and 120 degrees*. The probability function is a continuous function of the impact angle, over the range considered, and the function is symmetric about 90 degrees.

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*Impact angles greater than 90 degrees come into existence only because a reference system is taken with respect to the direction of the delivery aircraft at approach.

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Fig. 1 -- Arrangement of impact crystals for XW-5/F-101 design proposals (Systems 1 and 2)

RESULTS

In answer to question one of the INTRODUCTION, the maximized probabilities of impact of the weapon on any kind of spike-like object were calculated over the range of impact angles from 15 to 120 degrees. The calculated values are listed in Table I and are shown graphically in Fig. 2. It should be noted, however, that in the consideration of sensitive region geometry for impact fuzing devices, spike-like objects comprise relatively few of the objects in the totality of objects which can lead to damaging penetration of the warhead prior to detonation. The probabilities associated with impact on the edges of surfaces (not the surfaces themselves) are more than five times the probabilities associated with impact on spikes. Consequently, in the philosophy of contact fuze geometries, the first consideration (after the obvious one of protection against surface impacts) is protection against impact with the edges of surfaces. Caution must be used in attempting an interpretation of the values listed in Table I and shown in Fig. 2; the probability values given do not give the whole story.

TABLE I

Maximized Probability of Impact of the XW-5/F-101 Weapon on Any Kind of Spike-Like Object

Impact angle (degrees)	Maximized Probability
15	0.130
30	0.081
45	0.066
60	0.059
75	0.056
90	0.055
105	0.056
120	0.059

In reply to questions two and three of the INTRODUCTION, the calculated values of the maximized probabilities in question are listed in Table II and plotted in Fig. 3. (Total probability of damaging penetration is included in Table II and Fig. 3 for later reference.) Again, it must be remembered that the probabilities associated with impact on the edges of surfaces are more than five times the probabilities associated with impact on spikes and for the specific arrangement of impact devices under consideration (Systems 1 and 2), the probabilities associated with damage by edge-type impacts are roughly two times the probabilities associated with spike-type impacts over the range of impact angles.

TABLE II

Maximized Probabilities of Warhead Damage Prior to Detonation for the XW-5/F-101 Weapon with System 1 or System 2 Contact Fuze Capability

Impact angle (degrees)	Maximized probabilities of damage: Impact on spikes	Impact on edges	Impacts of all types
15	0.022	0.102	0.123
30	0.021	0.054	0.075
45	0.018	0.039	0.058
60	0.017	0.033	0.050
75	0.017	0.030	0.046
90	0.017	0.029	0.046
105	0.017	0.030	0.046
120	0.017	0.033	0.050

COMMENTS AND RECOMMENDATIONS

In the calculations of the maximized probabilities of damage presented in the preceding section, the fundamental assumption was that no gaps existed in the sensitive region geometries, the forward projections of which were annular. If this assumption is violated, the results are, of course, vitiated, and higher probabilities would be expected. Because of the fact that the XW-5/F-101 weapon has a thin skin, the assumption that no gaps exist in the sensitive region is questionable for the arrangement of four MC-300 impact crystals at Station 98.50 (System 1). (It may also be questionable for the arrangement of System 2). Two suggested designs (System 3 and 4) for the contact fuze capability were investigated as to associated probabilities of damage to the warhead prior to detonation.

One method to provide at least one annular projection of sensitivity for the same number of MC-300 impact crystals and networks (assuming that the reliability of the contact fuze system is unity) would be to remove the impact crystals at Station 30.00 and mount all eight crystals in two networks at Station 98.50, as shown for System 3 in Fig. 4. The calculated values of the maximized probabilities of warhead damage prior to detonation for the XW-5/F-101 weapon with System 3 contact fuze capability are listed in Table III and shown graphically in Fig. 5.

TABLE III

Maximized Probabilities of Warhead Damages Prior to Detonation for the XW-5/F-101 Weapon with System 3 Contact Fuze Capability

Impact angle (degrees)	Maximized Probability of Damage impacts of all types
15	0.127
30	0.081
45	0.063
60	0.055
75	0.052
90	0.052
105	0.052
120	0.055

A comparison of the over-all probabilities of damage for Systems 1 and 2 (Table II) and for System 3 (Table III) shows that the increase in probability of damage for System 3 is of the order of 0.005. Whether or not this increase is significant depends on more criteria than simply the absolute probabilities under consideration. If it is true that the arrangement of impact crystals in either Systems 1 and 2 does not provide an annulus of sensitivity at Station 98.50, then the increase (if any) in over-all probability of damage for System 3 as compared to System 1 and 2 is considerably less than the order of 0.005 and is probably not significant.

Another advantage of System 3 that must be taken into account is the simplicity of having just one mounting station for the impact crystals rather than the two separate mounting stations used in Systems 1 and 2.

The foregoing discussion has been predicated upon a completely reliable contact fuze system. If one assumes, however, that one network of impact crystals fails, then System 3 with eight crystals mounted at station 98.50 has a decided superiority over the two design proposals (Systems 1 and 2). The major contributions to the probabilities of damage attributable to impacts forward of Station 98.50 are the consequence of penetrations of the weapon case between Stations 30.00 and 98.50 rather than penetrations between Station 0.00 and 30.00. In case of failure of one crystal network of System 1, the two MC-300 impact crystals remaining sensitive (in the other network) at Station 98.50 probably would not provide a sensitive region geometry which would have a complete annulus as its forward projection, and, in fact, edges would probably have to be taken into account in the probability expressions. If edges must be taken into account (in addition to taking spikes into account) for an annular forward projection having gaps, the probabilities of damage would be considerably increased.

Note that the contribution to the total probability of warhead damage from impact on the rear region is at least three times the contribution from impacts on the nose region.

Ideally, a double-shell type system could provide the contact fuze capability for the XW-5/F-101, or any other, atomic weapon. If a double-shell type system is not feasible, the next choice of contact fuze system would consist of ring-type protection (designated as System 4), as indicated for the XW-5/F-101 weapon in Fig. 6. Note that the sensitive ring covers most of the rear region to the vicinity of the maximum diameter of the weapon case and all of the nose region with the exception of access space for the inflight insertion mechanism (IFI). The required rearward extent of the sensitive ring is a function of the following considerations:

1. Expected angles of attack,
2. Geometry of the contact fuze arrangement,
3. Sensitivity of the contact fuzes,
4. Transmission characteristics of the sensitive ring,
5. Delay time from impact to firing,
6. Geometry of the warhead, and
7. Amount of damage (penetration) the warhead can sustain without degradation of performance.

Note that all of the above considerations imply that the sensitive ring need not extend rearward all the way to the maximum diameter of the weapon. Furthermore, the probabilities of damage associated with impacts on the rear region diminish markedly with the additional protection afforded by the sensitive ring arrangement. The effect of rearward extension of the sensitive ring on the probability of warhead damage resulting from impacts on the rear region is illustrated by the calculated values listed in Table V and plotted in Fig. 7. The probability of damaging penetration decreases with rearward extent of the sensitive region of the sensitive ring mounted at Station 98.50.

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Fig. 6 -- Arrangement of ring-type contact fuze system for XW-5/F-101 suggested design (System 4)

REFERENCES

1. Memorandum, E. H. Draper, 1240, to K. W. Erickson, 5130, Probability Study on Impact Fuzing System of XW-5/F-101, November 2, 1954, Ref. Sym: 1240 (1685).

2. McAllister, C. R., On the Estimation of the Probability of Damage to Vital Components in Contact-Fuzed Atomic Weapons, Sandia Corporation, October 1954, SC-2875(TR).

3. Air Force Special Weapons Center, McDonnell Aircraft Corporation, and Sandia Corporation, XW-5/F-101 Weapon Status and Program Report, Sandia Corporation, August 11, 1954, SC-3245(TR).

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ADDENDUM

Sandia Corporation Technical Memorandum 283-54-51

(The author recommends that this addendum, prepared on 15 June 1955, be inserted following page 19 of the original Technical Memorandum.)

This addendum arises from a request* to re-evaluate the maximized probabilities of damage to the warhead (prior to detonation) for the XW-5/F101 weapon in light of new information from the latest gun test results.**

The essential changes between the calculations of Technical Memorandum 283-54-51 and those of this addendum are the following:

1. The angle of attack of the weapon is assumed to be at most 3 degrees for the recalculations, rather than the 5 degrees of the original calculations;

2. The sensitive region of the case is assumed to extend from forward of Station 30 to Station 120.00, rather than being simply two small annuli in the neighborhoods of Stations 30 and 98.5.

The calculations of the probabilities in question, with the changes listed above, result in essentially zero values for all impact angles. That is, the maximized probability of warhead damage prior to detonation may be quoted as zero for the XW-5/F101 weapon.

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* Memorandum, C. H. DeSelm, 1210 to K. W. Erickson, 5130, Probability Study on Impact Fuzing System of XW-5/F-101, Ref. Sym: 1210 (79), May 23, 1955.

** Rhodes, R. S., 1216, Crystal Impact Fuzing System Test on the XW-5/F-101 Type C Store, Technical Memorandum 114-55-12, May 31, 1955.

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