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NUCLEAR WEAPON SAFETY
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ABSTRACT

This report examines nuclear weapon safety as influenced by the introduction of widely deployed maximum readiness weapon systems. The report complements SC-4241(TR), a similar report published in February 1959. Recommendations for improvements in safety are presented with the goal of maintaining a satisfactory balance between peacetime nuclear safety and operational use requirements. The problem areas associated with deliberate unauthorized detonations are emphasized.

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SUMMARY

The purpose of this report is to analyze nuclear weapon safety as influenced by possible new weapon designs and current trends in operation concepts. Particular emphasis has been given to the safety ramifications resulting from the present and planned wide dispersal of weapons and quick reaction alert postures now being used.

Nuclear safety hazards which need further study and/or improvement are discussed in the following order:

1. Spontaneous equipment malfunctions
2. Environmentally induced equipment malfunctions
3. Accidental human actions
4. Deliberate unauthorized human actions

Recommendations are made for specific improvements in nuclear safety in order to maintain a satisfactory balance between peacetime nuclear safety requirements and operational use requirements. To achieve this balance, control and safety must receive increasing emphasis as important criteria, along with other operational requirements, in evaluating future weapon design concepts.

A brief history of the evolution and deployment of nuclear weapons, the AEC/DOD formal safety study system, nuclear weapon accident history, the present status of weapon manual content and dissemination, and the safety requirements given in Military Characteristics are discussed in the appendices.

NUCLEAR WEAPONS SAFETY

Introduction

In February 1959, the AEC weapon laboratories published a document, SC-4241(TR), which discussed the then current status of nuclear weapons from the standpoint of peacetime nuclear safety and recommended several possible improvements. At that time, the weapon laboratories had been participating in formal and informal weapon system safety reviews for approximately two years. The report was written primarily from this background of experience.

Several major changes in weapon operational concepts have occurred since that report, primarily because of the introduction of widely deployed maximum readiness weapon systems. Examples of maximum readiness systems include: bombs on SAC airborne alert, bombs on ground alert, strategic and tactical missiles on alert status, and air defense weapons. The last three examples apply to weapons which are deployed with both US and non-US forces. These new concepts of wide dispersal and quick reaction have modified many of the characteristics of the over-all nuclear weapon safety structure. In particular, the exposure of weapons to situations in which accidental or deliberate unauthorized detonations could result has been greatly increased.

This report examines the subject of nuclear weapon safety from the standpoint of the influence of these recent changes on weapon design and operational capabilities. Special attention is given to the problem of preventing deliberate unauthorized detonations.

The recommendations presented are aimed at weapon system features and procedural changes which will maintain an adequate level of nuclear safety within our understanding of present military operational concepts, and our expectations of future concepts.

Safety

General

Safety has always been an important consideration in nuclear weapon design. This consideration cannot be static. The continual change in stockpile composition and operational concepts requires a continuing review of the adequacy of nuclear safety.

In the ideal situation complete operational capability would be coexistent with maximum safety. It has been reasoned in some quarters that increased safety can be achieved only at the expense of degrading operational capability. The realization of a high degree of safety is not necessarily contrary to the achievement of required operational capability. Thus, while it is comparatively easy and straightforward to gain additional safety at the expense of degrading certain other operational requirements (readiness, for example), it may also be possible through judicious design and implementation of safety features to achieve a high degree of safety with negligible effect upon other operational requirements. In some cases certain operational requirements may actually be enhanced by increased safety; a higher degree of safety, for example, may make a higher degree of readiness tenable.

The adoption of an approach by which operational requirements are determined first and adequately safe weapons then developed to meet those needs has permitted the application of advances in nuclear weapon designs to changing deployment needs. Appendix A treats the history of weapons and deployment concepts, from the separable capsule and weapons-in-the-igloo approach of the late 1940's to the sealed-pit weapons in an alert status approach of today.

Design Approaches

One of the goals in the design of nuclear weapon systems is that the combination of failures or prematures which may result from the environments experienced in an abnormal situation will have a low probability of resulting in significant nuclear yield. This is, for example, the intent behind the requirement for at least two independently derived arming functions, ("two-point arming"). The "two-point arming" criterion has heretofore been primarily applied to the derivation of signals necessary for complete electrical arming of inherently one-point safe systems, i.e., no significant nuclear yield if the high explosive system is initiated at a single point.

In the case of inherently one-point safe weapons the prevention of electrical arming affords adequate protection against any significant nuclear yield. Under the guidelines of the past, significant nuclear yield has been taken to mean any nuclear yield greater than four pounds HE equivalent.

The advent of nuclear weapons which utilize mechanical safing devices to assure either one or multi-point nuclear safety has led to some redirection in emphasis in certain system design and analysis approaches.

In the case of weapons which assure one-point nuclear safety through the use of mechanical safing devices it is no longer sufficient to prevent only electrical arming. Premature actuation of the mechanical safing device would create a situation in which unacceptable nuclear yield could result if the weapon were involved in an accident or incident and subjected to a one-point detonation. Both premature electrical arming and premature operation of the mechanical safing device must be prevented. The "two-point arming" criterion applied in this case would require expansion to assure protection in both areas.

Similar considerations of nuclear safety in the case of weapons which assure multi-point safety through the use of mechanical safing devices indicate on the other hand that it is sufficient to protect only the safing device from premature operation to avoid significant nuclear yield. If premature operation of the safing device is prevented, significant nuclear yield will not result if the weapon is subjected to a one-point detonation or even a simultaneous multi-point detonation due to complete and proper operation of the electrical arming and firing system. The "two-point arming" criterion would in this case be most effectively applied to the derivation of signals necessary for operation of the safing device.

The type of safing technique utilized in a given weapon system, therefore, determines to a large extent the functions (and components) which are worthy of the greater safety emphasis and also the most effective approaches toward minimizing the probability of significant nuclear yield in the event the weapon is involved in an accident or incident. If monitoring is required, these same considerations must be taken into account.

Many techniques and general guides have been developed for designing and analyzing nuclear weapon systems to assure adequate nuclear safety. These techniques contribute toward nuclear safety through utilization of one or a combination of the following basic principles:

(1) Energy sources are isolated from critical components (such as the detonators or the mechanical safing material) by interposing several components which respond to different and independent conditions. In an abnormal situation these components are designed to provide either passive or active isolation. Arm/safe switches and thermal-sensitive fuse links are respective examples of passive and active isolation elements which are used. During the normal arming, fuzing and firing sequence these components perform active or passive transfer or transform functions.

(2) Energy is stored in such a state that it must be transformed to some other state in order to be utilized for the operation of critical components. Energy stored at 28 volts in a battery for example, must be transformed to a high voltage state in order to fire the weapon detonators.

(3) Energy of a magnitude significantly greater than that of most anticipated spurious signals is required for operation of critical components. The use of high energy detonators is an example of the use of this principle.

(4) Energy is derived from certain environments which tend to be unique to the weapon's normal mode of delivery for use either as the primary energy for operation of critical components or for control of other components which serve to transfer or transform stored energy for operation of critical components. Inertial generators and acceleration switches are examples of some of the devices which are used.

(5) Time interdependence is required between arming functions. For example, a requirement may exist that certain arming signals be received in a particular sequence or concurrently with other signals, thus reducing the possibility of arming from other than the intended sources.

(6) The "fail-safe" design approach is used to assure that component or subsystem failures, envisioned as spontaneous, environmentally induced, or as resulting from accidental human actions, will serve to safe the weapon rather than to arm it.

Safety Reviews

Formal nuclear weapon safety review programs have now been established by the Department of Defense and have been implemented by each of the services to study weapon designs and deployment plans. In general, these studies provide a good independent check of weapon safety features and use concepts at several points in the design and stockpile life of each weapon system. Appendix B describes how these reviews are accomplished.

Formal nuclear weapon accident/incident reporting systems have been established by each of the services. The investigation of causes and results of these accidents and incidents is an important tool in the design and analysis of safe nuclear weapons. A summary of the accidents to date is given in Appendix C.

The current number of weapons and their numerous exposures make a statistical approach more meaningful than it once was. Furthermore, the diversity of user groups and weapon system configurations makes a systematic approach essential. Increased attention should therefore be given to procedures for the centralized collection and publication of such data. In particular, attention should be devoted to accumulating relevant exposure data. The nature and extent of the data to be reported on individual accidents or incidents also merit continued consideration.

Nuclear Safety Hazards

Nuclear safety hazards can be conveniently categorized into four groups for further study:

1. Spontaneous equipment malfunctions
2. Environmentally induced equipment malfunctions
3. Accidental human actions
4. Deliberate, unauthorized human actions

Spontaneous Equipment Malfunctions

This type of nuclear safety hazard includes the type of accident wherein the various safing and arming devices in a given weapon spontaneously operate in such a way as to cause a nuclear explosion. Consideration of this problem must include all of the weapon, delivery vehicle, and support equipment which can either contribute to a detonation in place or can contribute to an accidental missile launch or bomb release.

An example of this type of design oversight or malfunction is the "sneak" circuit problem wherein individual elements of components or systems, each independently safe, may interact with each other to produce unexpected unsafe conditions. This problem is aggravated by the increasing difficulty encountered by any one group in the attempt to grasp or analyze the total weapon system in detail from the safety standpoint.

This type of safety hazard has been of concern since early weapon days. Design approaches which require several signals to arm and fire weapons and review procedures which look at over-all weapon systems are effective in reducing this risk, relative to the other hazard areas. Carefully instrumented weapon systems tests using war reserve quality weapons materiel and operational aircraft or missiles can be used to detect system incompatibilities or malfunctions. The current proposals for instrumenting weapon systems for use in Operational Suitability Tests are examples of AEC/DOD efforts in this type of testing.

Because of these design approaches and review procedures, the probability of a weapon premature from spontaneous component prematures within the weapon is, relative to other hazards, extremely low.

Environmentally Induced Equipment Malfunctions

This type of nuclear safety hazard includes any situation in which the external environment causes one or more components in a weapon system to function prematurely.

The type environments which must be considered can be grouped into three categories:

1. Single environments resulting from various accident situations such as fire or shock.

2. Multiple environments resulting from more severe accident situations (aircraft crashes, weapon jettison, missile explosion, etc.) such as combination of shock, deceleration, crushing and fire.

3. Extraneous environments such as RF fields, stray ground currents, or acoustical noise.

Although the environments of concern are not always predictable, considerable information is being accumulated on environments likely to be encountered in typical nuclear weapon accidents or incidents. The approaches used to minimize safety hazards in these instances include (1) the use of arming components which are either insensitive to or fail safe when subjected to particular environments, and (2) the design of systems such that the combination of failures or prematures, which may result from environments experienced in a given accident or incident, will have a low probability of resulting in significant nuclear yield.

Because of the multiple environments such as high shock and deceleration, fire, and crushing which are often associated with severe accidents, the design approaches which are likely to be more effective than a series of isolation elements are those which prevent arming either by precluding generation of energy that is compatible with the requirements of critical components or by dissipating stored energy in a controlled manner through the use of components which are self-disabling when subjected to an abnormal environment.

Because of the absence of complete information on present and future unusual environments, the probability of a weapon premature from environmentally induced equipment malfunctions can never be assumed to be negligible. However, the present level of knowledge coupled with the effort being expended on obtaining better information on unusual environments and designing with these environments in mind make this probability relatively small.

Accidental Human Actions

This type of nuclear safety hazard includes any situation in which human errors cause a weapon to receive sufficient input signals, electrical and/or environmental, to cause a nuclear detonation. These errors can range from improper procedures, such as trouble-shooting defective weapons with improvised equipment, to inadvertent acts, such as improper cable connections or operating switches on test or control equipment by brushing against them.

Since the advent of sealed-pit weapons and ready-alert conditions, this area of nuclear safety concern has become increasingly important, and has received much design and analytical attention. This attention must continue, since the field of human behavior is presently the least understood major factor bearing on nuclear safety.

The deployment of maximum readiness nuclear weapons with non-US forces has created a new set of problems. The language barrier, both in verbal and written form, can lead to misunderstandings in training. Differences in backgrounds of the non-US forces may lead to responses in unusual situations which might be completely unexpected to the U. S. way of thinking.

To date, many design and procedural techniques have been developed to minimize the safety risks associated with human errors. Handling safety devices, such as environmental sensing devices in warheads and trajectory arming systems in bomb and missile fuzing systems, are effective in most storage, transportation, testing, and handling situations, since they provide a series link which is less vulnerable to human error. Administrative procedures such as the two-man rule (no single individual allowed access to a weapon), use of safety-wires and seals on critical switches, use of authentication procedures involving more than one man before weapon commitment, and strict regulations regarding maintenance and handling allowed are effective throughout weapon life. However, the lack of predictability of human behavior and the ever-changing interplay between the weapons and the humans controlling them will require a continuous effort in searching for, and correcting, weak spots which may develop.

Deliberate Unauthorized Human Actions

This type of nuclear safety hazard includes any situation in which weapons are deliberately detonated without proper authorization. This could result from the unauthorized use of weapons by the crews based on faulty local intelligence or improper assessment of a nearby nuclear accident, from enemy sabotage, from psychotic action, or from the take-over and use of nuclear weapons deployed with non-US forces.

The nature of this hazard area, and its recognition, has changed considerably during the past year due to changes in operational concepts which require that large numbers of weapons be maintained in an alert posture, ready for use within minutes of authorization.

The design and procedural techniques presently in effect to protect against this hazard are basically those discussed previously under Accidental Human Actions. However, they are not necessarily as effective against deliberate actions, since the concern now is with cases where the individual or group wants the weapon to be detonated.

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This detailed information, once needed for repair and rebuilding of weapon components in the field, is not needed under today's practice of retrofit by component substitution.

Changes in deployment concepts have recently highlighted this problem and the increasing number of weapons on alert (hence, increased exposures) make this an important area of nuclear safety concern today which requires a great deal of design and analytical attention.

The increased interest in command control during the past year and the rather intensive study of feasible systems have indicated that concepts may be developed by which the hazards of deliberate unauthorized acts may be significantly reduced. Because these systems are treated in considerable detail in a recent document, SC-4587(WD), dated July 1961, which had similar distribution, they will not be discussed at length in this report. The referenced document should be considered as a companion report.

In particular, the use of remotely operated coded switches installed in critical circuits within the warhead or bomb would provide more positive control of the commitment of nuclear weapons and provide considerable protection against unauthorized acts. In the event of unauthorized commitment the coded command control system could in general prevent arming in the case of bombs, or in the case of missiles could prevent arming and provide for automatic destruction soon after launch.

Assessments of the over-all desirability or the broad value of any command control system must of course take account of other aspects such as the reliability and vulnerability of the associated communication systems. Caution is also indicated to insure that the incorporation of positive command control does not inadvertently create means by which a significant portion of our nuclear capability can be disabled by enemy actions, including enemy subversive actions.

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*Uncl Memo, Hertford, ALO, To Distribution, dated 10/27/60, MS/LCK ST60-471, "Atomic Weapons Design and Maintenance Philosophy (MDS-4)."

Techniques for increasing nuclear weapon resistance to tampering also hold promise in reducing these hazards. Schemes for increasing tamper resistance should have as their purpose one or a combination of the following:

(a) To delay or deny success in a passive manner by requiring special equipment, knowledge, and skills in order to gain entry and to perform the intended modifications without disabling the weapon.

(b) To delay or deny success in an active manner by confronting the would-be-tamperer with a "tamper consequence" through the incorporation of an active device which destroys or permanently disables the weapon in the event of unauthorized entry.

(c) To make evident, or at least make difficult the concealment of, the fact of entry in order to enhance detection and allow for corrective action.

Although passive tamper resistance has been increased for some newer weapons (sealed case warheads, for example), more effective anti-tamper schemes would require some revision in the present test and maintenance philosophies. Some logical compromise should certainly be possible. The anti-tamper features could, for example, control access to only the HE/nuclear assembly and the firing set.

Although active anti-tamper techniques for nuclear weapons have to date been investigated only briefly, this approach appears to have the greatest potential. In particular, the combination of an anti-tamper system with a command control system would provide effective protection against most hazards attributable to deliberate unauthorized acts. An ideal system of this type would prevent useful application of the weapon in an unauthorized manner even if unlimited information, equipment, skill, etc., with the exception of the proper code, were available. While this ideal is probably not attainable, it is feasible to make circumvention of the system sufficiently difficult by requiring an undue amount of time, skill, equipment, etc., that the unauthorized act will either not be attempted or, if attempted, will require a length of time which will allow for corrective action.

Although a firm design for an active tamper-resistant system is not yet available, the basic building blocks are rather clear. An effective anti-tamper system could consist of these basic elements:

1. The protected envelope or volume - the region of the weapon to which entry is to be denied.

2. The monitor - that device or technique which senses that entry has been gained or attempted.

3. The action transducer - the component which severely disables the weapon in such a way as to prevent its unauthorized use.

4. Source of energy (stored or derived) - necessary to translate the monitor's signal into the necessary action and to power the monitor.

5. A command control device - although not a truly basic requirement for tamper-proofing, this device (a coded switch, for example) seems an inherent part of any such scheme to allow for authorized access.

Recommendations

The recommendations which follow are grouped in the same order as the information in the preceding section; the order of presentation is not necessarily in degree of importance. A factor which should be considered when reviewing the recommendations is the basic approach to the solution. Some recommendations can be accomplished through strictly non-technical or administrative techniques, either by the DOD or the AEC. Others fall into a well-defined technical area and the ability to solve the basic problem rests with the designer. Still other recommendations represent a combination of these two approaches.

Spontaneous Equipment Malfunctions

1. Design practices and safety review procedures which consider the weapon system as a whole must receive greater emphasis.

For example, multiple carriage of mixed weapons (bombs and/or warheads) in Air Force and/or Navy aircraft must be considered as a potential source of sneak circuits. Before any such carriage is attempted, the complete system should be reviewed.

Environmentally Induced Equipment Malfunctions

2. Studies of present and future unusual environments, such as RF and acoustic noise, and the probable effects of these environments on weapon components which affect safety should be continued. Better definition of these environments is essential.

3. The use in critical safety circuits of components known to be sensitive to one or more anticipated environments (such as squib switch susceptibility to RF and fire) should be avoided.

4. Active self-disabling techniques should be further investigated with an aim toward enhancing nuclear safety in severe accident situations.

Accidental Human Actions

5. The need for, and the extent of, electrical monitoring of nuclear weapon systems should be continually analyzed to balance the gain against the potential cost.

The act of, or the provision for, electrical monitoring degrades safety to some degree because each electrical circuit which passes into the weapon offers a possible path for spurious or unwanted signals, such as RF noise, circulating ground currents, or unlimited tester power to be carried into the electrical system.

The risk of this causing trouble can be made quite small, but not zero. Therefore, the need for monitoring in any specific case should be weighed against this risk. Where a definite gain can be realized, such as monitoring of mechanical safing devices used to assure one-point or multi-point safety, care must be taken to minimize potential safety hazards that could result from electrical monitoring. In some situations, the best solution is to not monitor. Other monitoring techniques (visual methods, for example) can, where practical, provide an indication of a weapon's safety status while avoiding the aforementioned electrical hazards.

Deliberate Unauthorized Human Actions

In general, the recommendations in this section, although aimed primarily at deliberate actions, will also be effective against accidental actions.

6. Improved command control systems (such as coded control systems) should be seriously considered for all weapons deployed under ready alert concepts and for all weapons deployed with non-US forces.

7. The amount of information describing internal weapon functions contained in manuals and training courses should be restricted more than is presently the case.

Manuals and training are needed to prepare for possible future retrofits. However, with modern weapon systems, retrofits are by component replacement rather than by repairing at the weapon site. The extreme detail of some present-day manuals is unnecessary in the field, and may well serve to help the unauthorized user to detonate weapons in place or on a target. Appendix D presents examples of this problem.

8. Techniques for making nuclear weapons more tamper-resistant should be investigated.

9. Consideration should be given to techniques which would allow quick non-nuclear destruction or severe disablement of weapons which would otherwise fall into unfriendly hands.

Other Safety Considerations

10. Procedures for use by EOD (Explosive Ordnance Disposal) personnel should be carefully reviewed on a continuing basis for nuclear safety ramifications.

A nuclear weapon which requires EOD action because of an accident represents a serious nuclear safety hazard, since some of the safeguards may have been rendered ineffective by the accident. Such weapons may have, in effect, lost some of their inherent nuclear safety. Procedures to be used in such situations should be reviewed from a nuclear safety viewpoint by safety study groups. To be meaningful, however, these procedures must be derived and reviewed with the cooperation and technical guidance of the cognizant AEC laboratories.

11. Exposure information along with more detailed nuclear accident/incident data should be compiled and indexed at a centralized location.

This would provide basis for better hazard analysis and allow for proper orientation of design effort aimed at reducing the more significant hazards.

12. MC's should present safety requirements in terms of desired protection rather than in terms of design approaches.

Specific design requirements tend to limit the freedom of the designs in achieving the proper balance among the various design objectives. Usually, design approaches specified in MC's are based on the previous generation of weapon designs and as such may unnecessarily restrict future designs. The joint Sandia/LASL/LRL position on this subject was stated in a CRD memo,

[redacted]

Bradbury, Teller, and Molnar to Starbird, DMA, dated 6/22/59, with specific comments, recommendations, and "model" sets of MC's. Excerpts from this memo pertaining to safety are included as Appendix E.

13. Safety criteria for low yield nuclear weapon systems should be studied to see if existing philosophy is overly restrictive.

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The addition of a coded control system to the single-manned aircraft system may restore the intent of the two-man concept.

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APPENDIX A

BRIEF HISTORY OF THE EVOLUTION AND DEPLOYMENT OF NUCLEAR WEAPONS

For purposes of this discussion, the evolution of nuclear weapons can be related to three eras: early, intermediate, and present. The following sections discuss the interrelated factors of weapon design, operational concepts, and nuclear safety during each of these area.

Early Weapons

During the late 1940's, the weapons available were quite limited in quantity, very complicated, and designed for a single type of operational use, strategic bombing. Highly trained crews were needed to perform normal maintenance, and to prepare weapons for actual use. Strike preparation required many hours of complicated operations.

Nuclear safety during peacetime was assured by keeping the nuclear material completely separated from the rest of the weapon. Wartime safety was provided by maintaining this separation until the delivery bomber was on the way to the target.

The complexity and the logistic difficulties associated with these weapons were compatible with the operational concepts of that era; adequate warning of any need to use nuclear weapons was expected, the weapons were individually so valuable that reliability over the target was of paramount concern, and peacetime nuclear safety was essentially guaranteed.

Intermediate Weapons

During the early 1950's, the composition of the stockpile gradually changed. The numbers and types of weapons greatly increased. The relative worth of a single weapon decreased considerably, allowing attention to be focused on improving the operational features of the weapons. Extensive maintenance was still required, but strike preparation time was reduced to a few hours or less.

Nuclear safety during peacetime was still assured by physical separation of the nuclear material from the rest of the weapon. Wartime safety was provided by the use of automatic inflight-insertion (IFI) systems which permitted delaying the insertion of the nuclear material into the pit until shortly before the intended detonation time.

Again, these weapons were compatible with the operational concepts of the time, since adequate warning was expected, since wartime nuclear safety and reliability were reasonably balanced, and since peacetime nuclear safety was still essentially guaranteed.

Present Weapons

During the middle 1950's, the stockpile and the operational requirements continued to change. For reasons of nuclear efficiency, new weapon designs utilized the sealed-pit concept.

The continually increasing number of weapons and weapon types in stockpile began to impose oppressive logistic requirements on the users in terms of manpower, training, equipment, and facilities. This led to the concept of "wooden bombs," weapons designed for minimum (or no) maintenance or strike preparation activity.

Concurrently, progress in enemy delivery systems greatly reduced the warning time which could be expected. This led to the alert weapon concept now being used, wherein a significant portion of the stockpile is constantly kept in an alert position, ready for commitment within minutes.

These three concepts sealed pit weapons, "wooden" weapons, and alert weapons, although developed for different reasons, have meshed together to allow present-day nuclear weapons to be compatible with the operational requirements of today and the foreseeable future. However, this radically changed the nuclear safety picture. With the nuclear material permanently installed in weapons, nuclear safety considerations had to be expanded to include many new situations.

Current Status

Peacetime nuclear safety must now be assured by two secondary methods; design of nuclear/HE systems which are "one-point-safe," and design of arming and fuzing systems which provide adequate safety against premature operation. This latter factor can only be achieved by careful design and continuing review of the systems themselves and the continually changing conditions under which these weapons will be used.

An anomaly in the present stockpile compounds today's safety problem. Many older weapons, designed during the intermediate era, are still in use today. These weapons, while very safe under the operational concepts of their day, are not as safe as modern weapons under today's operational concepts. Their basic safety feature, the separation of the nuclear material from the rest of the weapon, is not consistent with a ready alert posture because of the complete "strike readiness" requirement.

APPENDIX B

NUCLEAR SAFETY STUDY SEQUENCE

The DOD, on June 10, 1960, published Directive 5030.15 which established a formal basis for safety studies and standards against which peacetime nuclear safety is to be judged. Each of the services subsequently published regulations implementing the provisions of the DOD directive. Although the service regulations differ in details, the salient provisions of the DOD directive are incorporated in each. Some of the more important features are:

Membership

a. To the extent practicable, individuals participating as members in studies and reviews should be other than those responsible for design, development or production.

b. The DASA and the AEC will participate in studies as members.

Safety Standards

The standards below are stated in the DOD Directive and repeated in each of the service regulations:

a. There will be positive measures to prevent weapons involved in accidents, incidents, or jettisoned weapons from producing a nuclear yield.

b. There will be positive measures to prevent deliberate arming, launching, firing, or releasing except upon execution of emergency war orders, or when directed by competent authority.

c. There will be positive measures to prevent inadvertent arming, launching, firing or releasing.

d. There will be positive measures to insure adequate security.

Safety Study and Review Procedures

a. As early in the development of a weapon system as significant data are available, an Initial Safety Study will be conducted to identify design deficiencies and provide guidance for further development.

b. Approximately 90 days prior to the system operational date, a Preoperational Study shall be conducted to determine the adequacy of safety features and to provide a basis for the development of safety rules.

c. Within one year after the operational date of a weapon system, an Operational Review shall be conducted to re-examine the adequacy of safety features, procedures and safety rules.

In addition, provisions are made for Special Reviews or Studies as necessary, based on the operational experience of a weapon system or modifications which may affect safety.

Safety Rules

In conjunction with Preoperational Studies, Safety Rules are established to provide maximum safety, consistent with operational requirements, during all phases of peacetime operation of the weapon system.

Reports

Formal reports of each safety study or review are submitted for approval of the appropriate service headquarters. Provisions are made for the inclusion of minority reports.

In conducting safety studies, the procedure is generally as follows:

> The technical design agencies present to the study group detailed information on component and system design including monitor, control, and test considerations. Where possible, hardware is made available for examination. The operating command presents a service-approved Plan of System Operation and Stockpile to Target Sequence which detail the planned utilization of the weapon system. The study group then analyzes this information and evaluates the adequacy of the system safety features. During the conduct of Preoperational Studies, a trip to a field location (a test unit or an operational unit) is made to examine the system hardware and proposed operational procedures.
>
> At the conclusion of the study, recommendations, where appropriate, are made to improve the overall nuclear safety of the system. When approved by the service headquarters, these recommendations become directive upon the appropriate agency.

After Safety Rules have been drafted and approved by the study group, the rules are forwarded to the service headquarters concerned for approval. After service approval, the rules are forwarded to the Secretary of Defense for DOD approval. The rules are then forwarded to DMA for AEC approval. Personnel from DMA, with representatives of ALO and Sandia Corporation, make a field trip to the unit in the most advanced state of readiness to review the rules, operational concepts, and facilities with which the rules will be employed. After this review, the AEC Commissioners approve the rules and they are returned to the Secretary of Defense for final approval and publication. When considered necessary, the Secretary of Defense can grant interim approval to proposed safety rules at the time of transmission to DMA for AEC approval. In the event the Plan of System Operation permits peacetime flying, the rules are not final until approved by the President.

APPENDIX C

RECORDED ACCIDENT HISTORY FOR NUCLEAR WEAPONS

DASA has provided definitions of accident and incident in TP 5-7 which permit our experience with weapons to be placed in perspective for an analysis of the safety implications.

Accident

An unexpected event involving a nuclear weapon or component resulting in any of the following:

1. Loss of or serious damage to the weapon or component.
2. Nuclear or nonnuclear detonation of the weapon.
3. Radioactive contamination.
4. Public hazard.

Incident

Any unexpected event involving a nuclear weapon or component resulting in any of the following, but which does not constitute an accident as defined above:

1. Incidents whereby the possibility of detonation or radioactive contamination is increased.
2. Individual errors committed in the assembly, testing, loading, or transporting of equipment, and/or the malfunctioning of equipment and materiel which could lead to an unintentional operation of all or part of the weapon arming and/or firing sequence.
3. Individual errors committed in the assembly, testing, loading, or transporting of equipment, and/or the malfunctioning of equipment and materiel which could lead to substantially reduce yield or increased dud probability.
4. Any act of God (natural phenomenon over which man has no control) resulting in damage to the weapon or component.

5. Any unfavorable environment or condition which causes damage to the weapon or component.

DASA and the services established procedures in 1958 under which accidents or incidents, as defined above, are reported and corrective action (design or procedural changes) initiated. Prior to 1958, there were no formal reporting or documenting procedures. The following table summarizes those accidents involving WR quality weapons of which Sandia Corporation has had official notification.

WR QUALITY NUCLEAR WEAPONS INVOLVED IN ACCIDENTS

Weapon	Date	Type Accident	Location	Cause and Remarks
	Feb. 1950	Deliberate jettison	Puget Sound, Wash.	Unknown.
DELETED	April 1950	Aircraft crash	Albuquerque, N. M.	B-29 crash. Weapon detonation. Detonators not installed.
	July 1950	Aircraft crash	Lebanon, Ohio	B-50 crash. HE detonation.
	Aug. 1950	Aircraft crash	Travis AFB	B-29 crash on takeoff. HE detonation.
TOTAL IN 1950 - 4				
DELETED	May 1952	Inadvertent release	Alaska	Component failure in aircraft release mechanism.
TOTAL IN 1952 - 1				
DELETED	Mar. 1956	Inadvertent release	Loring AFB	B-36. Defective aircraft wiring. Weapon dropped during run-up. Weapon did not burn or detonate. Six detonators smashed.
	July 1956	Aircraft crash	Overseas Location	B-47 crashed into storage bunker. No weapon burning or detonation.
TOTAL IN 1956 - 2				

Weapon	Date	Type of Accident	Location	Cause and Remarks
	May 1957	Inadvertent release	Kirtland AFB	Human error. Crew member of B-36 contacted exposed release cable in bomb bay. HE detonation.
DELETED	Oct. 1957	Aircraft crash	Homestead AFB	B-47 crashed on takeoff. Two low order HE detonations. Weapon burned four hours. Pit melted.
	Dec. 1957	Inadvertent release	Castle AFB	Inadvertent release during down-loading. No detonation or burning.
TOTAL IN 1957 - 3				
DELETED	Jan. 1958	Aircraft crash	Overseas Location	B-47 gear failure while taxiing. Weapon burned. No detonation. Capsule in IFI melted.
Mk 15	Feb. 1958	Deliberate jettison	Hunter AFB	B-47 involved in mid-air collision. DELETED No detonation.
DELETED	Feb. 1958	Inadvertent release	South Carolina	Human error. HE detonation. Civilian property damage. B-47 aircraft.
	Nov. 1958	Aircraft crash	Dyess AFB	B-47 crashed from 1500 ft. altitude after catching fire during takeoff. HE detonated high order.

OSD 6.2(a)

DOE b(3)

Weapon	Date	Type of Accident	Location	Cause and Remarks
DELETED	Nov. 1958	Aircraft fire	Chennault AFB	JATO unit inadvertently fired on B-47. Aircraft and weapon burned. No detonation.
TOTAL IN 1958 - 5				
	Jan. 1959	Fire in storage	Unknown	Faulty heater in storage buildings caused fire. HE burned. No detonation.
DELETED	Jan. 1959	Aircraft fire	Overseas Location	Three fuel tanks inadvertently jettisoned from a parked fighter aircraft. Aircraft burned. Weapon damaged by fire. No detonation.
	July 1959	Aircraft crash	Barksdale AFB	C-124 suffered power failure on takeoff and crashed. One weapon burned completely. No detonation.
	Nov. 1959	Aircraft crash	Hardinsburg, Ky	B-52 crashed after mid-air collision with KC-135, both weapons burned. No detonation.
TOTAL IN 1959 - 4				
DELETED	June 1960	Fire	McGuire AFB	Fire of unknown origin burned an alert BOMARC in its launcher. Weapon destroyed. No detonation.
TOTAL IN 1960 - 1				

Weapon	Date	Type Accident	Location	Cause and Remarks
DELETED	Jan. 1961	Aircraft crash	Goldsboro, N. C.	B-52 crashed following rupture of wing tank. Weapons separated from aircraft during breakup at 2000-10,000 ft. altitude. One weapon parachute deployed - weapon survived. One weapon "free-fell" and was destroyed. No detonation.
DELETED	March 1961	Aircraft crash	Yuba City, Cal.	B-52 crashed returning from "Cover-all" mission. Weapons left aircraft at or after impact and were destroyed. No detonation or burning.

TOTAL IN 1961 TO DATE - 2

TOTAL ACCIDENTS INVOLVING WR QUALITY NUCLEAR WEAPONS, 1950 TO SEPTEMBER 1961 - 22

SECRET

APPENDIX D

CONTENT OF MANUALS FOR NUCLEAR WEAPONS

The interpretation of requirements on manual content has received considerable attention in the last few years. The present AEC/DOD agreement regarding this problem is stated in the Atomic Weapons Design and Maintenance Philosophy document, dated August 16, 1960. Paragraph 5 of this agreement states:

> "Contents of Technical Publications which apply to the newer weapons and are given wide distribution will be limited to general information as a safety-security measure; however, critical detailed weapon information will be made available for restricted distribution, generally at the military depot level. For each new weapon entering the stockpile, the Technical Publication will specify what maintenance will be accomplished by the Military. This will be determined jointly by the AEC and the DOD."

To determine the effectiveness of this agreement, contents and distribution of manuals for two recent bombs, the B41-0 and the B43-0, were studied. Table I gives the manuals published, the copies in the original distribution, and the sensitive material in the contents for the B41-0. Table 2 gives the distribution of the -1 and -3 manuals to the military.

Table 1

Manual	Title	No. of A Series Copies	Sensitive Material
B41-0	Weapon Summary	555	Principles of operation, components to prevent sabotage named and described.
B41-1	Assembly Test, Storage, and Maintenance Procedures with Illustrated Parts Breakdown	600	Principles of operation.

Table 1 (cont.)

Manual	Title	No. of A Series Copies	Sensitive Material
B41-3	Maintenance Instructions with Illustrated Parts Breakdown	860	Principles of operation, complete schematics, location of components
B41-3A	Maintenance Instructions with Illustrated Parts Breakdown (Supplement)	200	Component location
B41A-3	Maintenance Procedures with Illustrated Parts Breakdown	555	None
B41-7	Fuze-Setting Procedures	510	Principles of operation

Table 2

Manual	Distribution Series	Number to DASA	SAAMA
B41-1	A	75	450
B41-3	A	200	450
	B	100	
	B (Revision 1)	400	400

Tables 3 and 4 give the same information for the B43-0.

Table 3

Manual	Title	No. of A Series Copies	Sensitive Material
B43-0	Weapon Summary	1205	Principles of operation
B43-1	Assembly Test, Storage, and Maintenance Procedures with Illustrated Parts Breakdown	945	Principles of operation
B43-3	Maintenance Instructions with Illustrated Parts Breakdown	1080	Principles of operation, complete schematics, location of components
B43A-3	Maintenance Procedures with Illustrated Parts Breakdown	495	None
B43-7	Fuze-Setting Procedures	940	Principles of operation

Table 4

Manual	Distribution Series	Number to DASA	SAAMA
B43-1	A	650	400
	A (Revision 1)	750	400
	A (Revision 2)	500	375
B43-3	B	650	373

Our understanding is that the -1 manual is the general information manual given wide distribution and the -3 manual is the detailed information manual given restricted distribution. From the actual distributions made on these two series of manuals, the intent of the agreement does not appear to be met. The reason for concern is even more evident when consideration is given to the fact that only 100 B41-0 Bombs are scheduled to be manufactured.

[redacted]

APPENDIX E

SAFETY REQUIREMENTS IN MILITARY CHARACTERISTICS

The following discussion is extracted from a CRD Memorandum, Bradbury, Teller, and Molnar to Starbird, DMA, dated June 22, 1959.

<u>Reasons for Recommending MC Revision for Safety Considerations</u>

"We have observed that safety 'requirements' grow from a single paragraph in the ICBM warhead MC's (Ref. 2)* to eight subparagraphs in the MC's for the XW-47 and lately to sixteen subparagraphs in the MC's for the SUBROC warhead (Ref. 3).* We protest that this more and more specific 'requirement' approach is not in the best interests of safety. We believe that a recent review of formal AEC/DOD agreements conducted by DMA staff illustrates that the AEC holds joint responsibility with the DOD for any nuclear accident which might occur. Therefore, we believe that the AEC must retain responsibility for the technical details of the design required to achieve the desired safety goals in its warheads. Evaluation of the degree of safety provided and the efficacy of the means of providing it is something that is, and should be, a matter of joint AEC-DOD concern. This is, of course, properly done in the various military safety evaluation groups which must retain freedom for study and recommendations.

"In safety, the attempt will always be to do the best that can be done consistent with operational characteristics of the weapon system and the reliability one wishes to achieve. Arithmetical analysis, based upon assumptions and less than adequate data, of what the system is <u>estimated</u> to be capable of affording has been seen to be open to many misleading interpretations resulting in 'absolute' interpretation of <u>calculated</u> safety and reliability levels.

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*References for these quotations are:

Ref. 2. SRD Military Characteristics, MLC to Distribution, dtd 2/28/56, Subject: Approved Military Characteristics for a High Yield Warhead to be used in the ATLAS Intercontinental Ballistic Missile, Q-57346.

Ref. 3. SRD Military Characteristics, MLC to Distribution, dtd 3/17/59, Subject: Military Characteristics for a Nuclear Warhead for the SUBROC Sub-Surface-to-Sub-Surface Missile, Q-81222.

[redacted]

"From the start of the atomic weapons program fifteen years ago the AEC and the DOD have been striving to achieve the highest degree of reliability that the state of technical knowledge would support. During this period two things of prime importance to the reliability problem have taken place -- we have gained some actual knowledge of the effects of passage of time on weapon components and materials and we have gathered an increasing amount of data on the operating behavior of many types of components under a variety of environmental conditions. It must be emphasized, however, that this increased knowledge covers a non-homogeneous and ever changing stockpile involving widely different design practices; so much so that there is very little data that is unquestionaly comparable. Almost all comparisons and predictions involve important assumptions that are easy to overlook. Despite this spongy foundation, both we and the DOD have seen an unmistakable improvement and have agreed that it was not ridiculous to strive for reliabilities as high as 0.995 in most weapons.

"It is clear that it is economically infeasible to accomplish enough testing to ever prove such a high reliability. It is also clear that the time that would be required to accomplish that large test program is completely incompatible with the nation's needs for new weapon systems. Both these statements can be made for all ordnance material, atomic or otherwise. Recognizing these facts we have worked toward the 0.995 figure as a goal, knowing that we could never prove that it had been achieved.

"Since it is impossible to prove that the goal has been achieved, it seems senseless to specify such numbers as requirements in Military Characteristics. We therefore believe that the intent of the DOD in phrasing Military Characteristics can be very adequately covered with a different set of words -- words which will permit a more quantitative measure of design worth. The attached "Model" MC's illustrate the point.

"The same statements can be made about "Safety Requirements." As stated before, safety and reliability often work against each other. Suitable trade-offs between them should be arrived at and recommended through normal liaison with DASA and the joint Service Working Groups."

Safety Considerations Sections of Model Warhead (Bomb) Military Characteristic

"The nuclear system shall produce no more than four pounds HE equivalent nuclear yield in the event of detonation of the HE by any means other than the intended firing system.

"All practical measures shall be taken in the warhead (bomb) design to minimize the possibilities of a nuclear accident as a result of human error or unauthorized or improper procedures.

"It shall be a design goal, to be evaluated by the best calculational techniques available, that the probability of a warhead (bomb) nuclear premature owing to system malfunctions in the previously unarmed warhead (bomb), and exclusive of human error, be predictably less than 10^{-6} and in consonance with other operational requirements of the weapon system applications."

NOTE: Separate model MC's, one for bombs and one for warheads, are given in the reference. Parentheses in the quotations above indicate the differences.

DISTRIBUTION:

1-10/75A - Librarian, Division of Military Application, AEC, Washington, D. C.
Attn: Development Branch
11-12/75A - K. F. Hertford, ALO/AEC
13-14/75A - USAEC, San Francisco Operations Office,
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1/1F - Org. 5613

1/1G - Org. 5530

H Series
1/2H - Org. 1712
2/2H - C.H. Spreul, 3428-2

J Series
1/1J - Jerry Wallace, 3416